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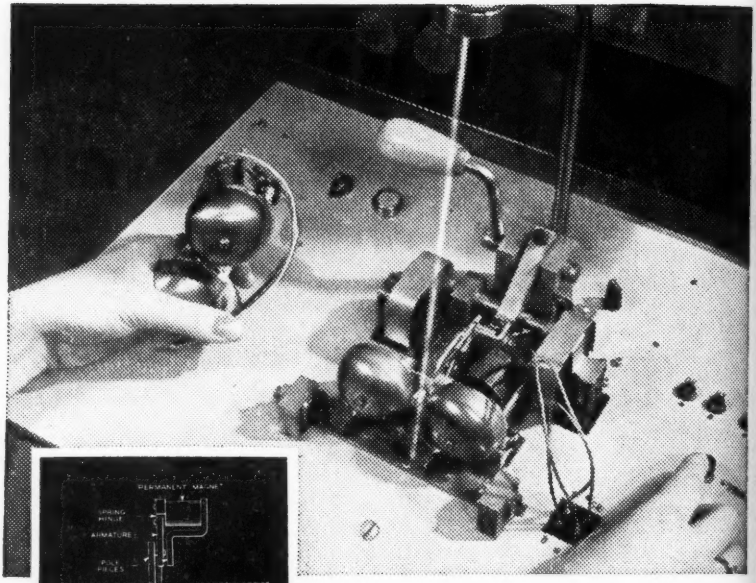
The American Society for Engineering Education



The Bell System's new automatic method of adjusting telephone ringers uses a beam of light passing between the gongs to a photoelectric cell. When test currents are applied to the ringer the machine decides whether to change the spring tension or the magnetic pull. After each change it tests again until the ringer is in perfect adjustment—and the whole procedure takes only 30 seconds.

It tells your "RINGER" when not to ring!

To YOU, it's your familiar telephone bell. To telephone engineers, it's a "ringer." And it has two jobs to do. It must ring, of course, when someone calls you. And it must overlook the numerous electrical impulses which do not concern it, such as those sent out by your dial.

Ability to respond to some impulses, to ignore others, requires exact adjustment between the pull of a magnet and a spring. If they are out of balance your telephone might tinkle when it oughtn't, or keep silent when it should ring.

In the past, adjustment was made by hand, little by little until the proper setting was reached. It took time. But now Bell Laboratories engineers have developed a machine which adjusts new ringers perfectly, before they leave the Western Electric Company plants where they are made. And the operation takes just 30 seconds.

This is another example of how the Laboratories work constantly to improve every phase of telephony—keeping the costs low while the quality of service grows higher and higher.

BELL TELEPHONE LABORATORIES

Working continually to keep your telephone service one of today's greatest values

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The Draft Deferment Policy for College Students*

By RALPH COOPER HUTCHINSON
President, Lafayette College

This statement by President Ralph Cooper Hutchinson, of Lafayette College, was made in defense of President Truman's executive order establishing a college student draft deferment policy based on high scholarships.

"Despite the well-reasoned statements of the President and Gen. Hershey, the distinguished university presidents Dodds and Conant still insist that 'a system of calling up all members of an age group who are physically fit is in accord with American ideals of democracy.' They deplore the deferment of college men with high qualifications, a deferment which is only to prepare these men for more effective service in the armed forces. This insistence is distressing because these university presidents are taken by the public to speak for American education. They themselves make no such claim but their very eminence and distinction serve to create that impression.

"American democracy has never claimed that all men should be regimented in the same pattern, do the same thing at the same time, assume the same precise responsibilities in an emergency, or be enslaved by equalitarian socialism. American democracy has, on the other hand, insisted that each man should do his part, that part for which he is best fitted, and in the time and manner which best serves the needs of our nation and our society.

The Dominant Force

"We are in what is either an all-out war or a protracted mobilization calculated to prevent world war. For the winning of either and the establishment of world peace, we know we must have unprecedented industrial production. This conflict may be won by the nations achieving the greatest scientific progress based upon the soundest and most extensive research. The fire-power so produced, and the transportation to be developed will require the finest and most mature skills for their strategic use. Moreover, it is clear that the idealogical aspects for this conflict may be the dominant force and the determining factor. As none before, this will be a contest of production, science, research, skill, and leadership in action and ideas.

"This means that any immediate expedient which cuts off the development of such skills and leadership is suicidal. First and primary consideration in planning for victory and for the successful preservation of our freedoms should have been the unhampered and uninterrupted training of scientists, production men, medical men, engineers, and qualified leaders for the armed forces and for the civilian programs. First measures on the part of politicians, militarists, citizens and educators should have preserved that thin red line of training of the best students available. First compulsion should have been that these men be required, not permitted, to continue their preparation for maximum service in this war.

* A reply to Presidents James B. Conant and Harold W. Dodds.

"The statement of these university presidents to the effect that the colleges and the college students do not want preferential treatment is correct. But it should make no difference to us what the colleges or the college students want. This mobilization economy should be planned intelligently for the attainment of victory for the forces of freedom. Students qualified and able to study should be prepared for their greatest ultimate usefulness to the armed forces. When they are ready they should be put where they are most needed. This is more nearly the true ideal of American democracy.

Intelligent Use of Skills and Abilities

"To insist, for example, that a brilliant medical student should delay his training for two years or more to carry a gun when he might otherwise go on to the completion of his medical and surgical skills is a stupid interference with the sound prosecution of war itself. It will not hurt the student concerned but it hurts the nation. And it is unfair to the men who will be in the front lines, deprived thus of one more desperately needed surgeon.

"The confusion in Congress and in the colleges is due to the fact that there has been no clear recognition of the primacy of education for the winning of the war. Apparently university presidents are afraid of their own truth for they above all others have failed to enunciate this need for trained men in a great national emergency. Devices for popularity with the voters, the public, the labor unions, the newspapers, and with government officials have obscured our national vision.

"It is time that everyone lay aside political considerations and concern for popular acclaim and think straight through to the defeat of our enemies and the enemies of free nations. It is time that we insist on the immediate, uninterrupted and increased training of doctors, surgeons, engineers, scientists, researchers, and leaders for all phases of military and civilian activity.

"This can be done without impeding the mobilization for the present conflict. Let's get away from this silly debate over socialistic equalitarianism, turn every man to his own task—even the student—let us push ahead, win this war, beat down this surge of human enslavement, and so establish peace on the earth. Such a program is much nearer to the true meaning of American democracy."

The Engineer, The Machine Age, and the World of Tomorrow*

By PHILIP SPORN

President, American Gas and Electric Company

It is commonly accepted that the industrial revolution was initiated in England and that it began roughly with the development of Newcomen's engine of 1705 and more definitely with the improvements made by Watt about 1774. At first this made it possible to do away with human labor for such backbreaking tasks as pumping and hauling. Then came the mechanization of scores of industrial activities: spinning, weaving, fabricating, and many others. And, because the power for these industries had to be developed in large units, the development of the engine eventually led to centralized industrial operations and to the subdivision of these operations, to large centers of activity and to concentration of population at these centers, with some good and many evil consequences.

But no such recognition has yet been given to the new industrial revolution which was made in the United States of America. This revolution is characterized by machine production, intense technological development, intense specialization, and a much higher rate of production per unit of human effort. That is to say, a great increase in productivity. It has been accompanied by and has enormously stimulated the spreading out of industry beyond the large centers. The development of electric power and its universal availability throughout the United States has been an important factor in this revolution. And an even more important factor has been the relatively negligible cost of the mechanical energy that electric power has placed at the beck and call of every worker in industry to lift and haul, cut and chip, hammer and weld, spin and weave, transform and refine, and to carry out the myriad operations in producing the profusion of goods and services available today.

As a direct consequence of this new industrial revolution, we have a standard of welfare unequaled in history.

American Achievement

Let us look at what has happened here in the United States over the past twenty-five years. In a small table I have compressed into four groups, A to D, a number of indicators of the change in the standard of living during this period. In Group A I have placed two fundamentals—life span and health care. Group B, covering the next four items, shows the data on national income, wages earned, hours worked and the consumers' price index. Group C includes three typical items commonly thought to represent amenities of living—passenger car registrations, telephones and radio sets in use. And finally, in Group D I have given data on two of the fundamental factors upon which the others, more immediately representative of the standard of living, are dependent: electric power production and steel production.

These indicators reflect a most remarkable achievement in the history of the advancement of human welfare. Who can fail to be impressed by the

* An address delivered at the 1951 Engineering Conference, Virginia Polytechnic Institute, February 23, 1951.

SOME INDICATORS OF THE CHANGE IN STANDARD OF LIVING IN THE UNITED STATES, 1925–1949

Group		1925	1949	% Change
A.	Average Male Life Expectancy at Birth in Year Indicated	57.8 Yrs.	65.4 Yrs.	+ 13.1%
	Hospital Beds per 1000 Population	6.9	9.9 ('47)	+ 43.5%
B.	National Income (Billions)	76.0	221.5	+ 192.0%
	Average Weekly Wages, Manufacturing Production Workers	$24.37	$54.94	+ 125.0%
	Average Weekly Hours, Manufacturing Production Workers	44.5	39.2	− 11.9%
	Consumers Price Index (1935–1939 = 100)	125.4	169.1	+ 34.9%
C.	Passenger Car Registrations	17,439,701	35,904,770	+ 106.0%
	No. of Telephones (Total U. S.)	16,935,918	40,709,398	+ 140.0%
	No. of Completed Calls Per Capita	194.9	355.4	+ 82.5%
	No. of Radio Sets in Use in U. S.	4,000,000	81,000,000	+1,950.0%
D.	Electric Power Production, Total-Billions of Kwhrs.	84.7	344.5	+ 307.0%
	Electric Power Production, Total-Kwhrs. Per Capita	743	2,310	+ 211.0%
	Steel Production—Short Tons	45,393,524	77,978,176	+ 71.8%
	Steel Production—Tons Per Capita	.391	.521	+ 33.3%

fact that in the quarter century 1925–1949 average life expectancy increased 13% and average weekly wages went up 125%, while weekly hours went down 12%. Or by the striking increase of 211% and 33% in per capita production of electric energy and steel—both of basic importance?

And yet, remarkable as this accomplishment is, there certainly can be no question that all is not well with us as individuals or as a nation, nor with the world as a whole. Among individuals, even in this country, there is no general happiness; in the nation there is no pervading satisfying and strength-giving pride of achievement with confident hope for the future; and abroad there is no peace, in many quarters almost no hope. Some would go so far as to say that no hope is being held out for the Western system of civilization—for all of Western man.

How are we to work our way out of the deep morass we seem to have gotten into? How are we to bring under control the forces we have let loose? If it is a fact that our difficulties lie in the failure of our economic, social and moral ideas to keep pace with the growth of technology, can we find our way back by declaring a moratorium on scientific and technological research and development? That has been suggested. Perhaps, it has been said, we can retrace our steps and set up islands of primitive simplicity and self-sufficiency. Is that the answer? Or is the answer an escape into other worldliness and the pursuit of a course that would through a religious revivalism lead to the replacement of our present civilization by a "World wide and enduring reign of the Church Militant on Earth"? That has been proposed by Toynbee.

I must admit that I cannot see any salvation in a return to ancient ways. It seems to me that we cannot go back. If one examines figures of energy, production for the civilized countries of the world, one finds startling discrepancies in individual use. Whereas, for ex-

ample, the kilowatt-hours produced per capita of population is around 2500 in the United States, it is a pitiable 2 in Pakistan, 4 in China, and only 14 in India.

What does this mean? Just this: On the average each human being in a country as technologically advanced as the United States has at his call 2500 kilowatt hours per year. In the less technologically developed countries the corresponding figure is not 1/20th of that value in some of the better cases, and as little as 1/100th in the worst. As a consequence, in those countries the human being is reduced to the role of an energy producer. But how can you reconcile man's humanity or his having been created in the image of God with the idea of valuing him and using him primarily as an energy producer? Keep in mind that the average healthy human being so used can at best produce 1 kilowatt-hour in the course of a twelve hour working day. No, it seems to me that a return to the path of pre-industrial development is not going to make things right. On the contrary, we must continue on the road along which we can lift heavy toil from the back of man.

Nor does the answer lie, it seems to me, in any religious revivalism. That does not mean a denial of the place religion and religous experience can occupy in the growth and enrichment of the human spirit. But I am convinced that such dislocations and maladjustments as we suffer from cannot be cured by neglecting them and going off into another sphere, by—to borrow an engineering term—mixing dimensions.

Which Way to Human Progress?

What, then, is the answer? Which direction can we travel? If we cannot go back to primitive simplicities—and barbarities—and if we cannot escape into a world of other-worldliness—then there is only one route left: continuation along the same route we have been traveling, the route of industrialization and mass production. But, if we follow that course, will that not lead to disaster—some of it almost directly ahead? I am deeply convinced that need not be so. Certainly not, provided we utilize the needs and respect the limitations of human nature as they have developed since the dawn of history, and provided we take advantage of the possibilities of enlarging both raw material supply and production, and the improvements in social relationships as these have been elaborated and tested by human experience. If, in short, we bring to our side a dynamic concept of human capability, if we test it realistically as we go along and if we carry it forward with faith in ourselves and in human progress and our ability to promote that progress.

In her book on the problem of survival facing the west, Barbara Ward observes that the ideas and aspirations of Western man are far from materialistic. They are in fact the most startlingly spiritual forces that have even affected society. Starting with an essentially static world there emerged some 3000 years ago new forces which wrought probably the most radical transformation of the human race since man became recognizable man. These are the Graeco-Judeo-Christian ideas which are the heritage and foundation of our modern Western civilization and in which the basic Greek contribution was rational vision and the Judeo-Christian contribution was moral vision. Out of that there grew man's desire to transform—and his belief in his ability to realize that desire; his desire to create; and his desire to seize on natural circumstance and to change and mold it to the use of man. Looked at from this perspective, it is the ideas of our *Western* civilization which stand out as the truly revolutionary ideas of the world and these are the ideas which must be carried forth if salvation is to be brought to man.

Shall we, then, retrace our steps? Denounce the industrial revolution? Try to arrest the second industrial revolution which in my view has already been going on a long time? Some, like

Norbert Wiener, think we are only heading into the second industrial revolution, but I like to think that it began some 25 years ago and what we are heading into now is merely its full development. This development is going to carry to much greater heights the present mass production techniques. Automatization, of which we have seen a good beginning, will, during this phase, be carried much further, aided by the use of such devices as the computing machine and the vacuum tube. We ought to encourage these trends and developments. At the same time, we need to give them leadership.

Authifarianism vs. Leadership

Where and how shall we get that leadership? It is not likely that we shall get it from those scientists and social scientists who use a secure position of authority in their own special sphere as a springboard for pronouncements about the world at large. Atomic energy has given us some good examples of this habit. Since Hiroshima there has been a great preoccupation with peacetime uses of nuclear energy—and a vast amount of nonsense on the subject by specialists whose knowledge of the world was too limited to furnish them with a sufficiently broad perspective.

We are told by these authorities that if only man were perfect he could now realize all the benefits of an atomic cornucopia, do away with want and disease and secure riches for all. Or again that the world can be set free by the atom if only the world will first set both itself and the atom free. The use of atomic energy for bombs, we are warned, has been allowed to compromise the very necessary potentialities of the long time use of atomic power to replace oil and coal which it is said are within centuries, if not decades, of exhaustion.

It is obvious that these views—taken from a variety of sources, which should be responsible—have this unifying trait: they ascribe almost supernatural powers to atomic energy that simply are not there. Because, stripped of its nuclear physics or the complex chemistry of its separation, and even more of the rhapsodic worship it has inspired, plutonium, U235 or U233, if any of them find use in production of energy, will find application to replace conventional fuels. True, if we can only bring about the solutions of a number of very difficult engineering and economic problems, they may become most superior fuels. Highly concentrated—one pound being capable of developing heat equivalent to that of fifteen hundred tons of bituminous coal—such fuel would be easily transportable. It thus holds out hope of becoming a universally available fuel; and, perhaps, a more economical fuel than coal, oil, or gas. The development of nuclear fuel may, therefore, bring lower-cost heat energy and particularly lower costs of generation of electric energy.

Is that important? Yes, very. But only to the extent that lower-cost fuel is an important item in the cost of electric energy. That means, therefore, that it would be very important in such operations as producing aluminum, magnesium, chlorine or titanium, and of almost no direct importance in ordinary industrial operations or in household use. But this admitted importance is hardly such as to warrant an assignment to the development of atomic power of a value as cosmic as those cited.

Admittedly, atomic energy lends itself to a certain amount of etherealization. In matters more familiar we should logically be more stable. But is there anything less realistic than the fetishism with which many have surrounded hydro-electric power and which is summed up in the remark of an otherwise responsible economist who asserts that steam-electric power is aristocratic while hydro-electric power is democratic!

Scientists, Engineers and World Problems

The remarks of scientists and social scientists to which I have been referring suggest a rather serious lack of compre-

hension on their part of the material world of today. One would expect that the very particulars in which their understanding is most inadequate could best be supplied by the engineer. After all, he is the one who developed and applied the machine technology which is the Western world's most conspicuous characteristic. One wonders why he does not have a larger share in providing the leadership which that world so desperately needs. Actually engineers are hardly represented at all in leading roles in public affairs.

The Cabinet of the most powerful democratic nation does not include a single engineer. In the 81st Congress of the United States there were only 7 engineers out of 432 members, while the legal profession, for example, furnished 259 men. There were only 5 engineers in the Senate, as contrasted with 66 lawyers. Or consider the sobering fact that among the commissioners of the three perhaps most important administrative bodies in the executive branch of the government—the Securities and Exchange Commission, the Federal Power Commission, and the Atomic Energy Commission—there is only 1 engineer, who serves on the Atomic Energy Commission.

I do not pretend to know what accounts for the engineer's aloofness from public activities. Perhaps it is simply that the environment of politics—in the best sense of the term—is too alien an atmosphere for one who has been taught to believe that the world is composed of solid facts, that its variables can be balanced by contingency factors and that any compromise is questionable. Whatever the ultimate cause, it seems to me that engineering is not widely represented in public affairs because engineers, consciously or unconsciously, have elected not to make the effort necessary to become involved. This condition ought to be corrected if, as I believe, the engineer has been and is the instrument through which the second industrial revolution is being accomplished.

Broadly speaking, responsibility for this inertia of engineers in public affairs, rests with the present generation of practising engineers. In saying this I mean that in the final analysis it is they who must be held responsible for the condition of our technical schools. They are the ones who propagate the new generation, and they propagate in their own image. What are they setting up as their image? In general, the definitions of engineering adopted by engineers stress the technical aspects of the field, and frequently along quite a narrow beam. The engineer thus restricts himself to the cramped role of technician. He does not even allow himself the breadth of field that goes with the concept of technologist.

Education and Outlook

Where does this narrowness of view and aim start? At least as far back as the beginning of the future engineer's technical education. It may well go farther back and have its beginnings in the preparatory or high school. It may very well be that here is molded in almost permanent form the ideas that engineering consists solely of the application of science to the design, construction and operation of machines and equipment or to the carrying on of process "for the aid and convenience of men"; that those studies and interests which contribute directly to these stated aims are proper and should be encouraged; and that other studies and interests are not only divagational but are somehow soft and inconsistent with such an obviously manly profession as engineering.

If that is so, then as far back as the upper levels of our preparatory schools it is necessary to introduce curricular changes which will emphasize the potential breadth of engineering and the engineer's role, and stress the socio-economic usefulness and importance of technologists in modern society. The future engineer must be made to see not only that he will join a profession of technologists but also that he should become an in-

fluential member of the much broader group who together are the architects of social progress, a circumstance that gives them boundless opportunities.

Equally important, we must make it clear that the very magnitude of the potentialities imposes heavy responsibilities on those who as educators undertake the task of molding and guiding the development of our future engineers. For it is the teachers in the preparatory schools who can best plant the idea that the role of the engineer is fully consistent with knowledge and understanding of the social sciences and the arts. As a matter of fact, I think the case warrants much stronger statement. A thorough grounding in the humanistic disciplines is indispensable to the engineer's full development and to his assuming any real leadership in the world of today.

The place to begin on this new road is the secondary school, but that is only spadework. The real work must be done in the engineering college or technological institute. And this will be impossible unless we recognize squarely that by and large our engineering education has tended altogether too heavily toward the vocational. The curricula in the schools that propose to train engineers in the fullest sense must be broadened; more time should be devoted to social sciences and humanities. This may mean a reduction in time devoted to the specific engineering subjects—the subjects which are supposed to impart practical know-how. But, if a choice has to be made between this know-how and the acquisition of broadly based knowledge of society, past and present, the answer should not be difficult. Not know-how, but an understanding of the process for acquiring know-how and how to use know-how is what we have to aim at.

The last, it seems to me, is of particular importance. There is a general feeling, certainly prevalent in the United States, that we have in the past absorbed too many facts and thought about them too little; this applies with particular pointedness to engineers and engineering education. A great Polish scholar and philosopher who lived and taught among us for many years first pointed out some 30 years ago that the essential characteristic that differentiates man from plant and animal life was that, whereas plants possess chemistry binding abilities and animals space binding qualities, man is the only creature on earth who possesses the unique capacity to accumulate knowledge. The engineer trained in science and engineering is apt to over-idealize this time binding characteristic of his profession. For there also exists in human experience much knowledge that is non-cumulative in the sense that the engineer's analytical methods and procedures, equations, formulae and tables are completely cumulative. The knowledge relating to literature, philosophy, music and art is of a quite different and infinitely less palpable kind. The broadening experience of these, no less than strictly technical study, is needed by engineers who want to assume a part in leadership in the world of tomorrow.

A significant step in expanding the scope of engineering education has been taken within the past year. Several of our leading universities had already demonstrated that the integration of technical schools within the university community, and the resultant close association between technology and the liberal arts, can do much to increase the effectiveness and vitality of all concerned. The new step is an extension of this idea. The idea is to enable the Institute to broaden and deepen its activities in these fields and to educate men to be effective citizens as well as effective professional engineers—to be, in other words, technologists and engineers and not mere technicians.

The mechanism for gaining this objective need not necessarily be the same in other engineering institutions, but the basic idea needs to be developed and implemented by many more schools. I haven't any doubt that only after this

is done will we succeed in establishing a satisfactorily broad foundation for training the better rounded engineers that the future demands.

Nor can any program for enlarging the scope and vision of our engineer stop with the schools. The present generation of mature and successful engineers have a responsibility in this process also. This involves the closer integration of the engineers with one another and with the professional schools and colleges: each with his own alma mater, most naturally, but also with the other institutions that his work and practice naturally bring him in contact with. So many engineers of outstanding ability, upon reaching maturity, rush headlong along a road that will keep them as far away from engineering as possible. In doing that, they separate themselves from engineering and engineers, and also from their problems and the institutions where these problems are being worked on. While many of the engineers in this group would be emphatic in their denials of any such intent, they nevertheless generally imply that the profession and practice of engineering is not quite a satisfying occupation, although it may be an excellent stepping stone to some "higher" or at least more "responsible" form of activity.

This, it seems to me, is a great pity. Because I believe that out of such judgment and action the engineers who have advanced in their profession not only lose an opportunity for spiritual expansion and satisfaction, but—and this is when the common welfare suffers—they fail to give the younger generation of engineers what they might otherwise be able to transmit of their own growth and development.

Such men cannot only teach and contribute by precept and example but also have an opportunity to propagate one of the most important ideas that needs to be implanted in the mind of the young and younger engineers—the dynamism of engineering. The tendency toward overawing the young engineer with the vast amount of accumulated knowledge that he has to acquire in turn tends to sterilize his creative faculties before they have had an opportunity to blossom. It is the older generation of engineers who can furnish out of their experience the necessary distillate to avoid such deadly thinking and to establish the vitally important truth that what an engineer learns in his years at school and in his early years of practice about what others have done before him is but a prelude to what can be done and what is open and possible for him to do as he matures in his profession.

It is the engineer educated in the basic sciences, the humanities and the social sciences and thoroughly grounded in engineering principles and ideas, who will find opportunities for constructive leadership. The engineer who is equipped initially with enough tools to begin working in his profession but who more and more relies on new ones that he acquires as he goes along—he is the engineer who can stay buoyed up by the spirit of growth and progress and who can imbue others with this spirit. It is this engineer, with his knowledge of the machines that characterize and make possible the world of today, who can not only help create the world of tomorrow but who, taking his proper place in public affairs, will also help run it for the physical benefit and spiritual advancement of man.

Building an Engineering Curriculum

By JOSEPH WEIL

Dean of Engineering, University of Florida

Someone has said that the ideas of a bride and a groom differ about weddings. So, too, do the ideas of what should be contained in an engineering curriculum insofar as students, alumni, and faculty are concerned.

The Engineering Council for Professional Development has given much thought to the development of a new brochure entitled, "The First Five Years of Professional Development." The first line in this book states "The most important person in this country today is the young man who has potential." It is the purpose of this discussion to consider what is needed to build an engineering curriculum to fit his needs so that upon graduation he can avail himself of the excellent information, counsel and guidance that he can secure from books.

A college curriculum should be designed so that it gives to the graduate an education that enables him to enter into his chosen life's work well-prepared. Certainly, it is not the purpose of the college curriculum to be a complete education, but rather it should be a basic education which will enable him to continue to add to his fund of knowledge and to grow in his chosen profession. Engineering is growing fast, and as it grows its literature becomes increasingly larger in magnitude and reading it becomes more complex. Only if the educational program is planned so that the fundamental sciences—physics, chemistry, and mathematics—become basic knowledge to the individual, can reading of technical literature be carried on with the necessary facility and interest.

Curricular Problems

What courses shall an engineering curriculum contain? The student for the most part would like to spend his entire time in the shop and laboratory and take classroom material which deals solely with machines and materials. If the engineering alumni group were contacted they would indicate that courses in speech, economics, psychology, law, advertising, humanities, sociology, etc. should be included in the curricula. The comparison of curricula of today with those of twenty years ago reveals some interesting factors. There seems to be no question but that a large amount of non-technical material has been included. Since the program, in general, is still a four-year one, it might be thought that these courses have been included at the expense of fundamentals and technical material. I do not believe that this is the case. I feel that the courses in physics, mathematics, applied mechanics, chemistry, are more comprehensive than ever before. Fundamental engineering courses of applied mechanics, thermodynamics and hydraulics are given in as great detail now as then.

In planning an Engineering curriculum, we must recognize that only a portion of our students become professional engineers. It is estimated that in June 1949 there were approximately 300,000 engineers of whom 150,000 were registered. I would hate to hazard a guess as to how many of the graduates of our engineering schools are earning excellent livings in either non-engineering work or in work closely allied to engineering who were not numbered among the 300,

000. It would seem to me that the number would be at least twice as great. Has an engineering education been a loss to these men—unhesitatingly I would say "no." But I do feel that for many of these men it would have been better if they could have substituted for some of the material now included in our senior year more non-technical subject matter. In this technological world in which we live, it would appear that just as there is a real place for general curricula such as are given in the arts and sciences colleges where degrees such as Bachelor of Arts or Bachelor of Science are awarded, there is similar place today in our engineering schools for a non-professional degree which might be called a Bachelor of Technology. Such a degree should not be confused with the so-called General Engineering degree which has been given, tried, and in many cases dropped.

The responsibility of the engineering college is basically far greater than to train the young man for mere technical proficiency. It must give him a general education that will make him cognizant of the underlying factors which affect our modern sociological and industrial world—for only as a well-educated professional man can the engineer of today assume a place of leadership in modern society. If he is to have a voice in the control of his brain children, he must be prepared, first of all, to be a good citizen. A broad and well-balanced curriculum should lead not to the production of mere technicians but to the making of well-rounded professional engineers. Properly trained professional engineers should be able to bring the findings of the laboratory into practical use. As the basic scientist uncovers new laws, it is the engineer who must make them available to mankind in a practicable manner. The successful engineer of today must not only know how to handle machines and materials, but must also be able to plan from the economic and sociological standpoints as well. To create products for an already full market will lead his employer to financial ruin. To manage employees in an unskillful manner leads to strikes. There is a feeling among many educators that we are including in our curricula neither sufficient technical matter nor enough educational material of a non-technical nature.

What is there about the engineering profession which gives us the right to believe that we can do by our educational process in four years what the other professions take six to eight years to accomplish? It is true that the graduate from our engineering school must serve an internship in engineering, but I think that is also true of most other professions. Should we give a course which would lead to a degree of Bachelor of Technology in four years and the Bachelor of Engineering degree after about two more years of study? I feel that this latter bachelors degree in the engineering subject should cover about the same professional content that our present bachelors degree covers but that there would be more material given of a non-technical and humanistic nature and that there would be more time devoted to the fundamentals of mathematics, drawing, English, physics, chemistry, mechanics, thermo-dynamics, hydraulics, etc.

On the other hand, it is not the purpose of this paper to discuss such a degree at this time. There are a large number of educators who are in sympathy with a change of procedure as indicated but who feel that they are forced to follow into paths which have been blazed by so many of our eminent engineering educators of the past.

In curricula building, it must be taken into consideration that the basic work of an engineer is to design or to apply a knowledge of design to his work. It is probably in this one respect that an engineer differs from all other professions in that he applies his knowledge of the basic sciences and the social sciences with his skill in order to design or to apply design principles. The engineer in charge of the construction of a bridge must have design knowledge in order that he can properly interpret the de-

sign which is handed to him; this is also true of many persons in operation, management, and other fields. If our curriculum is planned solely to meet this definition of an engineer, what can be said for perhaps 60% of our graduates who enter fields contiguous to engineering and who use a minimum of design principles? I think that everyone would agree that it is not the purpose of the engineering educator to eliminate from consideration these men, but full cognizance should be taken of the worthwhileness of the work which these persons are doing and that as we plan engineering curricula their needs also must be met.

Degree of Specialization

Another criteria of curriculum building is based upon the degree of specialization we should try to achieve. During the past century we have departed far from the original concepts of an engineer and today we are considering more and more detailed speciality groups. The attitudes of many colleges vary in this matter. Some have specialized to only a very moderate degree and few fields of specialization are offered, while in other cases there appears a staggering multiplicity of specialties. In some cases a form of specialization has been carried in another direction in that mathematics, physics, and the other basic sciences have been held to a minimum and what might be termed shop courses have been expanded. Under the guise of practicality, the program borders upon that of the technical institutes.

Basically, therefore, in setting forth certain criteria that we should consider in the forming of a curriculum we can certainly include the following: 1. The curriculum should be planned so that the graduate can engage in work in engineering fields under the direction of experienced engineers and can be of definite assistance to them in the same manner as the young physician serves as an intern and resident. 2. Furthermore, his education should be of such a type that after approximately four years of such internship he should be ready for rather responsible engineering assignments and should be able to appear before the examining board of any of the states and be in a position to successfully pass an examination for registration as a professional engineer. 3. The engineer, as an educated man, must have the ability to read and to appreciate the literature and philosophy which is so important a part of our modern civilization. His education should be of such character that it will enable the graduate to consider himself as a professional man who can live and associate with other professional men, discussing with ease and confidence the normal problems which such men as leaders of a community would normally discuss. It should not be limited solely to the mere technological aspects of his profession, but must recognize that the engineer as a citizen should take his responsibility for the governmental functions and social operations of the community.

It has sometimes been stated that the principle professional tools of the engineer are five: facts, concepts, principles, techniques, and judgment. Certainly in the planning of any engineering curriculum the first three of these have an important place. I think it will generally be conceded that the last two are secured primarily from the field of experience. Many years ago in discussing the work of the engineer I stated that upon graduation the young engineer will probably be employed on some project or in some factory where he will work primarily with machines and materials. If he does his work well, a time may come when in order to speed up production men will be assigned to him to assist him in speeding up the work. Then he must use the best methods of securing the best production with these additional men. Then, as he successfully performs in the new assignment, he will be given more and more administrative responsibilities and he will have to consider fiscal matters—money. And so the growth of

many engineers is along a path of Machines, Materials, Men, Management, Methods, and Money. Certainly, the handling of these six M's is part of what is termed the engineering method. What courses should be inserted in the curriculum to help the student not only during the first part of his path, but which courses will be of value to him as his path broadens?

Another aspect of the planning problem which I think should be given considerable emphasis is that since it is generally conceded that design is a very unique criteria of the engineering form of education, anything which can be done to further the student's design and professional consciousness must be considered as most worth-while. With this in mind, many schools have found that a thesis which involves some research or design is excellent for motivating the student in this general direction. Certainly, that student who selects some problem which differs from those of his colleagues and then endeavors to secure information which would enable him to write a thesis on the solution of that particular problem secures a feeling of professional well-being and creativeness that he cannot secure from stereotyped courses.

Selection of Major Field

Certainly a few decades ago, a student chose his major option. Then, having selected that option there were no electives and the courses that he had to take were assigned to him on the day he entered college. In the recent years, however, there has been a shift from that general direction and most of the schools do provide some electives. The choice of these electives varies with many schools. In some cases these are misnomers. While the word elective appears in the catalogue, the faculty advisor of the student practically forces him to take the courses that the department advises are needed for that particular field of specialization. There is a general feeling among educators today that the required essentials of every curriculum should be held to a minimum and the student given the opportunity to elect subject material which he feels will be of greatest benefit to him. We all recognize the danger of the student steering far away from that field in which he should take more work, to clear up deficiencies.

But then, too, in many cases it may be found that the responsibility for such decisions rests in no small measure with our own educational system. The engineering student is a serious one, and I think that given proper counsel, he will endeavor to build a curriculum for himself which he believes will give him the subject material which he needs most for success in his life's work. It has been our experience in counseling students that while at first considerable reticence is shown by many men in taking courses which we believe they need, by patient and continuous counsel most men recognize their needs and volunteer to take the courses.

The curriculum should be frequently studied and revised. However, it should not be done so often that the entire set-up is in a turmoil at all times. It seems that, in general, a curriculum can be kept fairly stable for a period of about five years, and changes that must be affected in that interim should be relatively minor. I recognize that there are many people who feel that instead of having a considerable shift of curriculum material all at one time that it is better to have it come in gradually. However, over a five-year period the total amount of change should not be very great and the number of course changes should not be too radical if the period be limited to this time.

The Faculty in building a curriculum must not overlook the fact that occasionally an instructor is particularly competent in some specialty field. Whenever this occurs—frequently when a new man is added to the faculty—there is an immediate urge to place into the cur-

riculum a number of new courses in specialty fields. This is certainly one way in which a curriculum may become overburdened with specialties to an objectional extent. On the other hand, it certainly should not be said that these experts should not be given an opportunity to present some of their specialty work as electives to students who wish to elect specialty courses in those fields. There is a stimulus and awakened interest which occurs when people deeply imbued with their subject matter endeavor to pour forth their knowledge. This type of work must be held in check, and certainly in many cases, it should be withheld for the graduate program.

While in the definition of an engineer the term "to design" is emphasized, this should not be taken to mean that it becomes the purpose of the curriculum to train a man to be a skilled designer. If the engineering curriculum is properly planned, there would not be sufficient time to do this and there are many other reasons why this can best be done after a man leaves college. However, the curriculum should be planned so there can be no question but that the student receives the fundamentals of engineering science which will enable him to grasp with considerable facility design technique after he leaves college. Through experience so obtained he will gain the requisite knowledge needed for his professional work.

In the building of a curriculum we must take cognizance of the fact that we have a responsibility not only to provide the technical content of the curriculum but also to provide for the ethical phases of professional engineering while the student is in the most formative period of his entire career. If the engineering profession is to become increasingly greater and command the respect of the non-engineer, there must be developed in the student a feeling of professional consciousness. It is not, perhaps, necessary that formal courses in ethics and professional practice be included in the curriculum. Nevertheless, it appears to be an essential duty of the educator to definitely determine that somewhere in the curriculum emphasis will be placed on such subject material as will awaken in every student a professional consciousness that shall stand him in good stead during his professional career.

We can liken the building of a curriculum to the building of a beautiful edifice. Such a building might be considered by several groups of architects and builders. The same material might be available to all of them. Yet, the edifice that would be completed would be entirely different in each case. On the one hand, it might be a beautiful building structurally strong, aesthetically beautiful, and functionally excellent. On the other hand, quite the opposite might be true.

The same course material might be available to several groups of educators in various institutions; and the completed curriculum may be apparently similar but yet would produce entirely different results. Besides the material contained in courses there is a philosophy together with many intangible factors which combine to produce the final results. If we pick up a catalogue and read a curriculum and then compare it with the curriculum contained in another catalogue, it will frequently appear that both are the same. Yet, there can never be an evaluation of the intangible factors which are a part of each of our educational institutions. It is, in no small measure, due to these intangible factors that our graduates now go forth from our American institutions to serve well—graduates of whom we may well be proud.

The Case Method of Teaching on the Senior Level

By J. F. MANILDI

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It is a common failing, in engineering instruction, to try to teach too much. The supply of courses generally available tends to exceed by far the basic requirements of an engineering curriculum. Competition is keen for the inclusion of specific courses in required curricula. The instructor frequently feels that he must at least make the student aware of all the refinements of a subject with which he (the instructor) is intimately familiar. The instructor may tend to forget that it took him years of study, teaching, and possibly industrial experience to acquire the knowledge himself.

It must be remembered that four or five years of college training by itself cannot result in turning out a "finished" engineer. The most that can be hoped for is that the product of college training will be well qualified for a period of "apprenticeship" in his professional field. The industry is quite realistic in its attitude toward graduating engineers in this respect. It does not expect that the new graduate will be capable of handling full scale technical problems, much less problems involving questions of policy, finances, management, personnel, etc. Nevertheless, the graduate must be capable of growing in ability and stature to the point where he can handle these problems, or he cannot be considered to be a success in his profession.

The function of a college training in engineering may thus be considered to be to reduce to a minimum the "growing pains" associated with the graduate becoming a full fledged engineer, and to equip the student so that the transition may be accomplished in a minimum of time consistent with the students' native capabilities. It is virtually impossible to eliminate these "growing pains" for doing so would be tantamount to turning out of college an accomplished engineer.

To accomplish the feat of properly training the student for his "apprenticeship," the standard college curricula prescribes instruction in the basic sciences: mathematics, physics, and chemistry. It further prescribes instruction in the basic engineering subjects of mechanics, thermodynamics, electrical theory, fluid mechanics, properties and strength of materials. There is general common agreement that these are necessary.

A third group of courses are the so-called "electives." Courses of this type are designated either to give the student more specialized knowledge in his selected field of engineering, or to broaden his scope of learning in related fields. In either case, the objective is the same, namely to train the student so that his subsequent attainment of full professional engineering stature will be accomplished in a minimum of time with minimum growing pains. The method of accomplishing this objective is quite obviously different in the two cases. In contrast to the general engineering subjects mentioned above, there is a wide divergence of opinion on the type of courses that should be offered in this third group.

A course which we shall call Engineering Problem Analysis, as described below, falls into the third category and is the type of course designed to broaden the

students knowledge rather than to specialize his learnings.

Description of Course

The proposed course in Engineering Problem Analysis would consist of the presentation, discussion and analysis of typical industrial problems. The case method of instruction would be used throughout, with no attempt being made to present any formal instruction. No effort would be made to graduate the material in order of difficulty or complexity. The typical course would consist of three or four one-hour class meetings per week, or possibly two two-hour classes per week.

A total of from five to ten cases would be analyzed each semester. The cases selected for analysis would cover as many phases of engineering as possible with the time available. Cases would be selected, with as little modification as possible, from actual industrial problems. As far as practicable, different cases would be discussed each semester. This would insure up-to-date material for the course, and would suppress any tendency for instructors to guide analysis toward "pat" solutions previously worked out, thus suppressing original initiative on the part of the students. Experience in teaching the course would, of course, constitute the most effective guide to the selection of cases.

The cases themselves might vary widely in nature. For example, a case might deal with the design of an instrument required to do a specific task, or of the design of a particular component of a machine. At the other extreme, a case might deal with the inauguration of a full scale research program in a broad field of endeavor associated with a company's activities, such as the oil refining or aviation industry.

Every effort should be made to include all significant factors in the presentation of the problem material. It would be desirable to simulate as closely as possible the situation as it would actually exist in industry. Thus, not only the technical features of a problem, but also the pertinent economic, personnel, scheduling, plant facility, customer relations, and sales features of the problem as well.

The techniques of classroom instruction would be directed to encourage a maximum of contribution from the students with as little guidance from the instructor as the situation would permit. It would be desirable to use several men to teach the course, each presenting a case problem drawn from a field with which he is intimately familiar. Group participation in the solution of problems should be encouraged or even required. Solutions could be presented informally, orally, in class by individual groups, with criticisms from other members of the class or solutions could be presented formally in report form. A combination of both methods would probably be most effective. The instructor would act essentially as a moderator in this activity, keeping the discussions along constructive lines and furnishing factual information whenever desirable.

The usefulness of examinations in a course of this type might be questionable. One hour class period would not lend themselves to case problem solutions. The two-hour period would be more adaptable to examinations. Useful information regarding a student's accomplishments might be gained in a three-hour final examination. However, the necessity of examinations in a course of this type is highly questionable. Effective handling of the subject matter would require that enrollment be kept low, probably not more than twenty students per class. The course administrator would probably have little difficulty, without examinations, in judging the accomplishments of the individual students from the classroom discussions and the written reports.

Objective of Course

The basic objective, of course, in presenting students with a course of this type, is to better his adaptability to in-

dustrial problems and environment, and hence to increase both his initial and ultimate contribution as an engineer. The specific, immediate objectives, through which it is hoped that the basic objective will be attained, can be described as follows:

(a) To train students to synthesize the technical knowledge obtained in separate undergraduate technical courses. Students ordinarily capable of handling textbook problems in electrical theory, or thermodynamics, or fluid mechanics are frequently at a loss in attaching broader problems involving considerations from all these fields. This is one of the present failings of our engineering curricula, due primarily to lack of coordination among the separate subject matter courses and to an unhealthy tendency to depend too strongly on "canned" textbook problems for instruction.

(b) To enable students to acquire a facility for handling problems which they have not previously encountered. The difference between success and failure in a job assignment is often dependent upon the degree to which a man can readily adapt himself to a totally new set of conditions. There exists an understandable psychological tendency to use familiar methods of approach on new problems, or, worse, to be frightened into inactivity by a totally new situation. This tendency must be understood and overcome before any measure of success can be attained by a man on the job.

(c) To impress the students with the necessity of "selling" their recommendations or proposed solutions to problems. Altogether too frequently technically trained and competent men feel that their job is done when a well-executed analysis has led to a reasonable set of conclusions. The fact of the matter is that this is only the first step in the ultimate execution of the plan. Alternative methods of approach may, and generally do, exist. The engineer on the job must make every effort to sell his recommendation to his superiors, who, in many cases, may not be technically trained, or his proposal, however good it may be, may die an unnatural death in a filing cabinet. This necessity, in our present day of competitive enterprise, of selling a recommendation, is as real and important a responsibility as the more generally recognized responsibility of performing a consistent, satisfactory analysis. This is a responsibility which must be recognized and met if advancement in stature and position is to ensue. Our present training of prospective engineers leaves much to be desired in this respect.

(d) To acquaint students with logical, rational methods of handling problems that have no single "answer." Many problems, in fact, most problems encountered have many possible solutions. The number of variables involved generally vastly outnumber the quantitative relationships among these variables. Many existing relationships, particularly in connection with economic and personnel factors, because of their complexity, cannot be adequately represented quantitatively. Intelligent estimates, enlightened guesses and methods of approximation must be resorted to and these must be supported by convincing reasoning. It is not to be supposed that a student can be taught to do this adequately, since experience is the most valuably ally in solving such problems. Nevertheless, an appreciation for the necessity of using sound basic reasoning, rather than "handbook methods," can be taught and can result in the student's being much better prepared to handle problems of this type.

(e) To teach students to formulate the specific problems which must be attacked to arrive at a satisfactory set of recommendations with respect to a broader, more general problem. Present engineering education places a heavy emphasis on solving problems that are adequately stated, with little or no emphasis being placed on the formulation of problems. The young engineer thus frequently finds himself at a loss because no one tells him what he should do. The exercise and development of ingenuity and imagination in the formulation of

problems is as important as the ability to solve them once they have been stated.

(f) To teach students a little of the "art" of engineering in various fields. It is generally agreed that the "know-how" of engineering must be predominantly acquired through experience, and that is much more difficult to teach than the science of engineering. Nevertheless, by having case discussions led by men of wide experience and competence in their respective fields, it is possible to pass on a limited amount of this "know-how" and thereby to reduce in some measure the growing pains of the new graduate.

(g) To acquaint the student with the importance of recognizing his own limitations. One of the major difficulties which confronts a young engineer of little experience is that of deciding when a problem requires the application of knowledge or abilities which he does not possess. This situation is made increasingly difficult because it is not readily distinguishable from the case where he is giving up too easily because the problem only seems to be beyond the grasp of his capabilities. Danger lies in the application of to little knowledge to a situation requiring a thorough understanding of a phase of subject matter. There is a delicate balance between giving up too easily on one hand and recognizing the necessity for more competent help on the other. Doing the former or failing to do the latter are both sins which have an adverse effect on the reputation and advancement possibilities of the engineer.

(h) To teach students the importance of deciding in advance the desired degree of accuracy required in a problem analysis, and to plan his method of attack accordingly. In all problems it is necessary for the analyst to postulate an ideal system which approximates the actual system, and which is amenable to quantitative analysis. This is true even in the simplest problem, such as the problem of predicting the frequency of oscillation of a mass suspended from a spring. The degree of difficulty of the solution, as well as the probable error in the final answer or recommendations, depends on the complexity of the postulated ideal system. Unnecessarily complex postulates result in an expenditure of time and effort not warranted by the specific problem at hand. Furthermore, the analysis tends to be less readily understood by others, and the problem of selling the recommendations to superiors who are not so highly specialized in the field is a more difficult one. On the other hand, over-simplification of the ideal system will result generally in solutions having too great a probable error, and completely erroneous conclusions may be drawn therefrom. In this connection checks by alternative, approximate, methods of solution are highly desirable and should be encouraged.

(i) Other objectives may be indicated, such as teaching students to make full use of all available data, to work effectively in groups, to express himself orally and in writing clearly and concisely, and to recognize and carefully evaluate suggestions of others. These are self evident and will not be discussed in detail here.

Objections to Course

There are many objections which may be raised toward the presentation of such a course on the senior level. Some of these are anticipiated and will be discussed.

The displacement of other subject matter from the curriculum may constitute a valid objection. It is difficult to make any generalizations in connections with this objection, since the desirability or undesirability of replacing a particular course with the course described above would depend on the specific course which would be replaced. The responsibility of making a decision cannot be avoided by simply making the course an elective, since staff members must advise the students in making an intelligent choice.

The objection may be raised that it is not possible to present students, in a problem statement, with all the facts that he would normally have at hand in the actual industrial situation. This, of

course, is true. This objection is not as significant as may seem at first, however. An engineer is never confronted with a problem in which he has all the desirable data. There is always information, technical or otherwise, which would be useful in arriving at a solution, but which is not available. It might thus be argued that this lack of data which would normally be available is a blessing in disguise in that it tends to emphasize an existing situation and the student will be made more acutely aware of this ever-present characteristic of actual problems in industry.

It may be proposed that a course of this type will tend to severely confuse a student with too great a mass and too great a variety of material in a short time. It must be admitted that herein lies a real danger. In order to justify its existence, the course must be capable of instilling in the student a reasonable degree of confidence in his own ability to attack situations presented in the case material. To confuse the student, to make him doubt his capabilities would indeed constitute an overpowering objection to the existence of such a course. In this connection, it can only be emphasized that the selection and administration of case problem material must be done with great care. The course administrator and the individual instructors must work together very closely. More individual attention must be paid the students by the instructor than is generally necessary in other courses. Individual student shortcomings must be recognized and corrected. Otherwise, an adverse effect may result. It is true that at the beginning of the course, even the better students will tend to be confused by the problem material. This is not objectionable as long as the confusion and insecurity disappear and is replaced by confidence before the course ends.

It is possible that a course of this type may tend to give the student a distorted impression of the type of activity in which we will be engaged when he first gets a job. He may become dissatisfied, in retrospect, with the course, or with his job, when he finds himself doing strictly routine work. This difficulty can be overcome very readily by making it quite clear to the students at the onset of the course that the course is intended to enhance his long range achievement potentialities, and that no specific effort is made to prepare him for his first job.

Past Experience

The basic nature of the course discussed above is certainly not new. Many graduate schools, notably in law and business administration, have depended entirely on the case method of teaching in their curricula. The results, in these instances, have been highly gratifying, since adoption of the method is increasing. Engineering graduate schools have used the method sporadically and no good information is yet available as to its relative effectiveness. The Carnegie Institute of Technology, at the instigation of President Robert E. Doherty, has for some time presented on both the graduate and undergraduate level a modification of this type of course. At Carnegie, the emphasis is placed more heavily on the strictly technical features of a problem.

Courses of this type have constituted a part of the General Electric Advanced Training program for many years. This may constitute a recognition from industry that the normal engineering program at universities lacks in this type of training.

Conclusion

A course of the type described aims at filling into an engineering curriculum training of the type that is normally lacking. This training revolves around the simulation of actual industrial situations. Basically, it is hoped that a course of this type will make the transition of a graduate from an engineer-in-learning to full professional status, easier. Further, it is hoped that his potential of attainment in the profession will be increased.

The course is not proposed as a cure-all. As a matter of fact, it is proposed with the knowledge that certain adverse results may obtain. It is clearly recognized that the attainment of the specific objectives listed above, with a minimum of the indicated adverse results, requires very careful administration of the course.

In the News

The Engineering Manpower Commission of Engineers Joint Council today announced that its first report on "Utilizing Engineering Manpower" is available. This report, issued as E.M.C. Bulletin No. 1, brings together procedures to be followed in requesting necessary occupational deferments and delays for both reservists and non-reservists (draftees). The Bulletin also includes a brief statement on the problems of both government and industry in selecting and utilizing its technical personnel.

Because of the extreme critical shortage of engineers coupled with an increasing demand for engineers for defense purposes, it is believed that E.M.C. Bulletin No. 1 will be of much value to many employers and users of engineers. Copies may be obtained from Engineering Manpower Commission, 29 West 39th Street, New York 18, New York, at a nominal charge of 25 cents to cover the cost of handling and mailing.

Eleven of the nation's top scientists were named by President Truman to a Science Advisory Committee of the Office of Defense Mobilization, to advise the President and Mobilization Director Charles E. Wilson in matters relating to Scientific Research and development for defense.

Chairman of the group will be Dr. Oliver E. Buckley, who for the last 10 years has been President of Bell Telephone Laboratories, and now becomes Chairman of the Board of Bell Laboratories.

The other members of the committee are: Dr. Detlev W. Bronk, President of Johns Hopkins University and of the National Academy of Sciences; Dr. William Webster, Chairman of the Research and Development Board; Dr. Alan Waterman, Director of the National Science Foundation; Dr. Hugh Dryden, of the Interdepartmental Committee on Scientific Research and Development; Dr. James B. Conant, president of Harvard University; Dr. Lee DuBridge, President of the California Institute of Technology; Dr. James R. Killian, President of the Massachusetts Institute of Technology; Dr. Robert F. Loeb, of the College of Physicians and Surgeons of Columbia University; Dr. J. Robert Oppenheimer, Director and Professor of Physics at the Institute of Advanced Study, Princeton, and Dr. Charles A. Thomas, executive vice president of the Monsanto Chemical Co.

As outlined by President Truman in his letter of invitation to Dr. Buckley, the committee is to be available:

1. "To provide independent advice on scientific matters especially as regards the objectives and interrelations of the several Federal agencies engaged in research of defense significance, including relevant foreign relations and intelligence matters.

2. "To advise on progress being made in dealing with current scientific research problems of defense significance and also concerning defense research matters which need greater attention or emphasis.

3. "To advise concerning plans and methods for the implementation of scientific effort for defense.

4. "For transmitting the views of the scientific community of the country on research and development matters of national defense significance."

The Textbook from the Publisher's Point of View

By E. P. HAMILTON

President, John Wiley & Sons, Inc.

The writing of an engineering or scientific textbook is a major task, as I am sure all authors and publishers fully recognize. The longer I am in this business of publishing, the more I realize this, but nevertheless it is a job worth doing and I hope that I will say nothing to discourage prospective writers.

Before talking about textbooks themselves, it might be appropriate to say something about the function of the publisher. No doubt most teachers, and certainly all authors, have a pretty good idea of the publisher's function, but I have found that there are many people who seem to have little understanding of what a publisher really does. For example, I recall that when I did a good deal of traveling for my firm, salesmen in smoking compartments often asked me what my line was. When I told them publishing, they at once assumed that I was a printer. When I explained that no, we did no printing, they probably reached the conclusion that we were a sort of agent for the printers, or some variety of middleman who later, after the book was published, became a salesman. It is true that a publisher, is among other things, a sort of midleman, but I do not think it hard to convince people that as a middleman he has a useful function to perform.

The publisher is able to assist an author in many ways. In order to make a book useful to a large number of teachers, the publisher brings to the author the benefit of his long experience and often a larger view of the educational scene, as well as current information on courses as given in various institutions, which he gathers from his field men. A book is a costly undertaking, and if it is to yield a fair return to the author and the publisher, it must be so organized as to be suitable for use in a goodly number of colleges.

Wherever possible a publisher likes to work closely with the author in the development of his book as early as he can. Perhaps the author has notes which he is using in his classes; in fact, usually the best books result from such use. If the publisher can see these notes and go over them with his editors and advisers, he can often make suggestions to guide the author in writing a book that will have wide acceptance. On the other hand, tryouts of the sort mentioned above, particularly if continued for several years, can be trying on the student. It is doubtful that a student takes mimeographed notes as seriously as he does a textbook published in regular form. The president of a large state college once remarked to me that in his opinion there were too many mimeographed books in use on his campus. He added that either these notes should be published in book form after a short trial or the author should abandon his notes and find a book that came as near as possible to suiting his needs.

Rather frequently the pubisher may anticipate a need and search out an

* The three papers on textbook planning were presented before the Electrical Engineering Division at the Annual Meeting of the ASEE, Seattle, Washington, June 20, 1950.

author with good background to develop a book. Again, an author may also anticipate a need and write a really pioneering book which may result in courses being developed at other institutions. Unfortunately, with present-day costs this sort of pioneering, however desirable, cannot be encouraged to the same extent as in the so-called "good old days."

Pre-publication Preparation

When the author has his manuscript in final form, a careful editing for uniformity of such details as punctuation, abbreviations, references, etc., is called for. This work is carried on by the publisher. The selection of type, format, and binding is also a function of the publisher. This he does in consultation with the author. The preparation of illustrations also calls for close cooperation and consultation between the author and the publisher.

Finally, after the book is published, it is, of course, the duty of the publishing house to look after all details of advertising, marketing, and distribution. This is a big subject on which I could speak at great length, but it does not appear to me to be especially pertinent to this particular discussion.

I think all his indicates that a publisher has a very important function to perform; in fact, because of his close association with the author, the publication of each book becomes a separate small business, or even sometimes a fairly big business enterprise, in which the author and the publisher are joint partners.

What constitutes a good textbook? Undoubtedly many of you can answer this question better than I. I think, however, that we can all agree that a good textbook must cover adequately and develop logically the subject to be taught. At the same time it must be teachable.

Teachability and Style

Teachability is something not easy of simple definition. It is a combination of many things—clear writing, proper development of the subject matter, clear definitions, good illustrations, together with such aids as worked-out examples, carefully selected problems for solution, and possibly chapter summaries. The organization of a textbook should be such that it can be broken down readily into a group of assignments of appropriate length. This is not always easy to do, as the length of courses may vary, but this practical aspect of teachability should at least be given consideration by the author.

Concerning styles of writing in textbooks, there are as many different styles as there are authors, but anyone through whose hands goes a steady flow of manuscripts, year after year, learns to recognize certain types of writing. Many of the manuscripts that are offered any publisher are in a style that can be called flatly pedestrian. The facts are there, but they are presented without any leavening agent. Such books are like a meal out of cans, eaten from a bare board. The calories and nourishing values may be adequate, but the consumer craves the appetizing qualities that stimulate digestion.

Directly opposed to the pedestrian is a style which could be described as pretentious. I might hesitate to mention this selfconscious style as one that is found in textbooks, but the fact is that it is, and sometimes under distinguished authorship. For example, one well-known author once told me that he was afraid he was thinking more of the impression he wished to make on his professional colleagues than on the student when he wrote his first edition. Again I might cite the comment of a reviewer of a manuscript, who remarked that the author appeared to have one eye on the student reader and the other on the members of his profession. At best the pretentious style is characterized by "gobbledygook"—when the author means "lights must be put out," he says "illumination is required to be extinguished"; at worst this style descends to the ineptly ornate, and the embarrassed reader meets statements about "those fruits upon which the pre-

ent status of network theory rests" or "the dawn of engineering that is slow and ponderous." Such a style has no place in a textbook—not even in the preface to a textbook.

One expects a certain dignity in a book intended for study. Some subject matter, indeed, positively demands a formal presentation. Mathematical subjects, especially, and much of engineering and advanced physics and chemistry, and nearly all statistics can be conveyed mostly by equations and formulations. Chattiness is out of place, if not impossible, in dealing with such material. A bare, functional style is inseparable from the essence of such subjects. Yet even in exploring such rarefied reaches of the mind, some gifted writers can occasionally come down to earth and, still maintaining their dignity and self-respect, adopt a more informal, man-to-man approach. By similes and examples (and even metaphors, as long as they do not become mixed) they can simplify the difficult and make it more readily grasped. This is not as easy as it sounds.

I recall once saying facetiously to Professor William H. Timbie, "Writing of elementary books seems to be easy for you." With characteristic vehemence which I shall not attempt to reproduce he replied that this type of book was the very hardest to write and that he devoted much effort to rewriting and polishing before he was satisfied that he had an understandable result which was at the same time accurate.

The danger in simplification, of course, is that the process may be carried too far and degenerate into the distortions and inaccuracies of the popularizer. When an author breezily brushes aside difficulties and high-handedly pretends that none exist, he is doing his subject an injustice and being unfair to an intelligent reader.

There is no one ideal style. The good writer is full of his subject matter. He sees into it and all around it and can view it in perspective. He is aware of his audience: a specific group, with known background and with definite limitations, whom he had an overwhelming desire to reach and enlighten. He is sufficiently at ease to be himself and flavor his writing with his own personality. Such a man, with the aid and advice of a publisher, should produce something worth-while.

If style is defined as the manner of presentation, the publisher can make some valuable contributions himself. His staff editors can suggest actual changes in writing at the time they are going over the manuscript for editorial details. His production department will select, in consultation with the author, a format and a type which will certainly enhance the author's style, and a proper paper to avoid eyestrain. All these procedures will complement the author's own efforts. Textbooks of twenty or thirty years ago had a noticeable similarity of appearance. Today publishers devote considerable time and talent to making books attractive; they have stimulated the design of new type faces and are using the old ones more effectively. The approach each new manuscript with an open mind, recognizing its individual characteristics and planning a format suitable to its content.

Before leaving the subject of style, something, I think, should be said on nomenclature. Uniformity of nomenclature is highly desirable, as is adherence to the systems prevailing throughout a particular branch of science. We have known books employing nomenclature and terminology in favor among only a minority. It goes without saying that such nomenclature might easily prevent wide acceptance of a book.

Good illustrations are an essential element in a textbook, but they should literally illustrate, not decorate. A well-executed diagram or graph often may be a greater help to understanding than an explanation in words. To be most effective the illustrations should be really integrated with the text. The author who finishes his writing and only then sets out to "collect his figures" will not be

likely to have very good illustrative material.

Services of the Publisher

As all of you know, manufacturers are very willing to help authors in obtaining appropriate copy from which illustrations can be made. Further, engineering departments of the larger companies have offered to aid authors by going over their manuscripts and offering suggestions for changes in line with the latest practice.

Although illustrations are certainly aids to teaching, there are other aids which might be mentioned, for example, worked-out examples, which are often followed by problems for solution or questions, varying in difficulty and numerous enough to permit a teacher to make selections.

The matter of chapter summaries is perhaps a debatable subject. Some teachers maintain that the student should be able to do his own summarizing. On the other hand, summaries can prove very effective in a book, particularly one of a more elementary nature. In addition, good bibliographies, particularly in books of a more advanced character, are certainly called for.

Besides the teaching aids found in textbooks, there are visual aids, which publishers have been considering and even developing in certain fields. My own firm has already issued visual aids in fields other than electrical engineering, and we are now investigating the possibilities of visual aids in that field, not only as supplementary pictorial and graphic material, but also as a means of presenting complicated and involved diagrams and formulas which the instructor must use from day to day. This is a means of saving the lecturer tedious and time-wasting drawing and redrawing. We have followed with interest the experiments of Professor S. G. Lutz and Professor R. G. Kloeffler along this line.

How inclusive should a textbook be? Should it contain material which, although not strictly a part of a course, should add to its value as a reference? Corollary to this is a tendency of some authors to include material which is not actually needed by students but which the author wishes to get into print. Perhaps a moderate amount of such material might be permissible, but if it would add a chapter or two to an already sizeable book, it must be excluded for economic reasons.

Economics of Textbook Publishing

And speaking of economics, perhaps this is as good a place as any to mention that this subject is, I am sure, a disturbing one today to author, teacher, and publisher alike. The cost of producing books has soared in the past eight years and especially in the last five. Just as an example, a few months ago I compared the cost of producing a new edition of a textbook today with its original cost in 1941 and found it to be nearly three times what it was then. Some might ask if in a new edition parts of the old book could be saved. The answer is almost always, no, for the cost of plate alterations is such that one might as well reset. Illustrations can sometimes be re-employed, but even these may have become obsolete and need expensive corrections.

In setting prices for new books and new editions it could be suggested that since everything costs double or more what it did in the prewar period, we charge double for a textbook. Reasonable though this may seem, I am sure that doubling of prices would mean doubling up of students on the purchase of books. We publishers, of course, have had to charge somewhat more for our books than in the prewar era, but not double, certainly, except on specialized books. Temporarily, at least, the situation has been saved by enlarged college enrollments, greater industrial demand, and greater foreign sales, which have permitted larger printings. But, truly, the total outlay for textbooks is a small item in the cost of an engineering education today.

A perfectly natural question to be asked by engineers and scientists is "What is the publishing industry doing to

lower the high cost of books?" A brief answer, stripped of details, is that research is in progress, some of it sponsored by publishers, and although the results are slow in appearing, expectations are indeed encouraging, especially in new methods of type setting.

In conclusion, I hope I have been able to bring you something of the publisher's point of view and what he considers to be the important characteristics of a good textbook. Throughout my talk, I have stressed the importance of quality both in content and in format. To be worth his salt, a publisher must share the high standards of great teachers and must always discourgae careless and mediocre work. By so doing, he should be able to contribute to the development of a strong technical literature.

Commission on Engineering Education

At the request of the Supreme Commander for the Allied Powers, the American Society for Engineering Education and the Unitarian Service Committee, Inc. are jointly organizing a Commission on Engineering Education to visit Japan this summer.

Fifteen Americans, representing the principal areas of engineering education, will leave for the Orient in early July to consult with the Ministry of Education of the Japanese Government, as well as with educators and administrators of engineering colleges in Japan. SCAP has appointed the USC to handle administrative arrangements.

Dr. Harold L. Hazen, Head of the Department of Electrical Engineering at Massachusetts Institute of Technology, is Chairman of the Commission. Miss Dorothy Snavely of New York City, Assistant Director of Medical Projects of the Unitarian Service Committee, will be Executive Officer.

The Commission's itinerary includes Tokyo, Hiroshima, Osaka, Kyoto, Fukuoka, Sendai and Sappora.

Harry P. Hammond, Dean of Engineering at Pennsylvania State College, and Howard L. Brooks, Associate Director of the USC, have organized the Commission.

Persons appointed by the Committee on International Relations of the ASEE to serve on the Commission are: C. W. Beese, Industrial Engineering; A. B. Bronwell, Communications; W. R. Chedsey, Mining Engineering; A. G. Christie, Mechanical Engineering; A. G. H. Dietz, Structural Engineering; B. F. Dodge, Chemical Engineering; H. L. Dodge, Physics; R. B. Finch, Textile Technology; H. L. Hazen, Electrical Engineering; A. L. Miller, Mechanics & Structures; J. A. Sauer, Engineering Mechanics; E. W. Steel, Sanitary Engineering; H. B. Walker, Agricultural Engineering; F. L. Wilkinson, Administration; R. S. Williams, Metallurgy.

Textbook Planning from the Point of View of Teacher and Author

By H. H. SKILLING

Chairman, Department of Electrical Engineering, Stanford University

The general theme of this discussion is the possibility of little better planning of textbooks. To me, that seems to mean that we are discussing something to be done before the book is written. Perhaps it means some kind of guidance to be given the prospective author, with the object of urging him to produce a book that comes close to fitting the needs of his prospective customers. Speaking as one of the customers, that sounds fine. I am not sure just how it is to be done. But let us examine how the customers, and how the authors, operate at present, and see what seems to be possible.

We, who are teachers, know what we want when we select a textbook. We don't all want quite the same thing, fortunately, but I suppose the one fundamental need that everyone will agree on is that he wants a book to fit the course he is teaching.

How do you choose a book? When you teach a course, do you adapt your presentation to fit the best available book, or do you require the textbook to match your method of presentation or do you use books for reference only?

Speaking as a typical teacher I might say that it is my personal preference, at least for undergraduate courses, to adopt a good book and make the course fit the book. There are problems in fitting a course to an available book, but there are worse problems in establishing a course, deciding just how it is to be taught, and then trying to select a book to fit the course, and the biggest difficulty is that you generally can't find such a book.

What do you do then? Obviously, you write a book. It is a fine way, but rather laborious. It was this business, I think, of writing books to keep the courses going that the Preacher in Ecclesiastes has in mind when he said: "Of making many books there is no end; and much study is a weariness of the flesh" (Eccl. xii, 12).

If you are like me, and are willing to adapt a course to a good book, it seems that there is some hope for the idea of attempting to influence authors to write books the way we teachers want them. All that is needed is to find, somehow, a large enough group of teachers, all of whom want a book of about the same kind, within limits of the teachers' adaptability. The needs and desires of this group of teachers are then conveyed, how I don't know, to people interested in writing a book of this nature. Perhaps one or more good manuscripts will result from this process.

But there are several rather difficult problems, and the worst problems all revolve about this question: is it likely that a group of teachers can specify what they want in a way to result in excellent textbooks?

Suppose a group of teachers of electronics, for instance, get together and decide they want a book written according to a certain plan. Someone starts working on it, and in three or four years the book appears on the market. Now: (1) do the teachers still want it, or have they changed their minds, influenced either by trends in teaching or changes in the sub-

ject matter of electronics; and (2) is it possible that an independent author, more brilliant or more inspired than the group of teachers, or perhaps just giving a greater share of his time to thinking about it, may come through in the meantime with a better book—a book that even the teachers themselves will agree is better than what they asked for?

What Motivates the Author?

Speaking of authors brings in the other side of my dual subject—the point of view of the authors. If you go to a prospective author and say: "This is the kind of book that the customers want," will he write it, and do a good job?

Why do authors write books, anyway? We seem to need to know what motivates an author before we can decide what we can get him to do for us. What is it that makes a man undertake this "weariness of the flesh" that the Preacher speaks so feelingly about?

One reason I have already mentioned: you, as a teacher, want a book to fit a course you teach, and the only way to get a satisfactory book is to write one yourself.

Then some write for money, and happily the arrangements under which textbooks are printed are such that a very respectable amount of cash rolls in to reward a man who has produced the kind of book that we teachers need. It is common enough to hear slighting remarks about the lack of financial return from a published book, but this is sheer swank. Books that sell do pay.

Then there are those who write for reputation. Some write for a scholarly reputation, and some for a general public reputation. Erasmus knew about these people when he wrote, "The Praise of Folly" four and a half centuries ago. He said—or, rather, he made Folly say, "The ones who write learnedly, for the verdict of a few scholars, seem to me more pitiable than happy, since they continually torture themselves: they add, they alter, they blot something out, they put it back in, they do their work over, they recast it, they show it to their friends, they keep it for nine years; yet they never satisfy themselves. As such a price they buy praise—and that the praise of a handful. They buy it with so much loss of that sweetest of all things, sleep, so much sweat, so many vexations. Add also the loss of health, the wreck of their good looks, weakness of eyes or even blindness, poverty, malice, denial of pleasures, premature old age, and early death. The scholar considers himself compensated for such ills when he wins the approbation of one or two other weak-eyed scholars."

This speech, you will understand, is from the mouth of Folly, who is not to be taken seriously. She thinks more highly, she says, of "those who blacken paper with sheer triviality. . . . For these are crazy in a far happier way. It is worth one's while to see how pleased authors are with themselves when they are popular, and pointed out in a crowd." And though this speech may be by Folly, and written a hundred years before Shakespeare's day, it still paints two perfectly valid reasons for the writing that is being done today: professional reputation, and common fame. We all love it. And a variant of this is the more local prestige that an author gains with his Dean and with the President of his own college. As Lord Byron said, "'Tis pleasant, sure, to see one's name in print; a book's a book, although there's nothing in't."

One of the rewards of authorship is that publicaton carries our words to so wide an audience. Every author, I think, is happy that his ideas may reach a thousand pairs of eyes, through publication, where they could reach only ten pairs of ears in lectures. Some have the greater glory of seeing their thoughts, in print they cannot themselves read, going to teach students in countries that they themselves will never see.

And to this spread of a man's influence over the face of the earth, publication even adds a certain degree of im-

mortality. Perhaps his work will live on. Some authors' do. Don't you sometimes feel, as I do, better acquainted with an author who is long since dead than with some of your associates among the living? To a good many authors, it is no small matter that their teaching will continue after they, themselves, have vanished. Edward Gibbon wrote his famous "Decline and Fall of the Roman Empire" with the expectation, he says, that it might "perhaps, a hundred years hence still continue to be abused," and he was modest, for it has now been 175 years, and it is still being abused. "In old age," he says, "the consolation of hope is reserved for . . . the vanity of authors who presume the immortality of their name and writings." And Henry Fielding hoped "to be read with honor by those who never knew nor saw me, and whom I shall neither know nor see."

Then there are those who write for the sheer pleasure of writing. Where some men play chess, and some solve cross-word puzzles, other take pleasure in finding the exactly right expression of their ideas. The choice of the right phrase, the dove-tailing of ideas, brings delight. Do you know the verse from an author in a Carinthian monastery of a thousand years ago that starts like this: "I and Pangar Ban my cat, 'tis a like task we are at: hunting mice is his delight; hunting words I sit all night."

Finally, some authors write to promote an idea or an individual interest of their own; to convert readers to their own belief or point of view. It is not necessary to look to politics for examples of this. I know from my publishing friends that many an author tries to use his book as a sounding board for his hobby. Indeed, it would be rude of me to mention the examples I can think of in half the books I know. I believe it is rather an unusual author of a textbook who does not give some unjustified space to a method because it is his method, or to the results of research because it is his research, or to an argument because he wants to proselyte—not to teach.

Motivation and Results

That makes six or seven reasons for writing textbooks. These may not be all the reasons for which authors write, but they are enough. And the question is this: will these motives act to make an author write the kind of book we think he ought to write, to fit the purposes that we propose? Let us review them.

1. If you write for your own classes, your book may be shaped to fit a general need if your class is a typical class. On the other hand, it must not be forgotten that many of the most important books come out of classes that are pioneering in a new presentation, and nobody can guide the author.

2. If you write for money, naturally a plan that will increase your sales will be heartily welcome.

3. If you write for fame and public reputation, you will be pleased with a plan that will make your book more widely read.

4. But if you write for recognition among the learned of your own profession, your ideas of what your book should contain will not be open to much persuasion.

5. If your pleasure is in extending your influence to a wide family of students, extending over the world and continuing through the years, you want a book that will be beneficial to many readers—yet, at the same time, you want it to be personally and individually yours.

6. The man who writes for the simple pleasure of writing will not care to be restricted by any such guidance, and

7. The writer who has a cause to support or a hobby to ride will lose interest if he is restricted; if his favorite topics were sheared back, as I suppose they would have to be, he would find that his salt had lost its savor.

Now the fact is, of course, that every man who writes a book is motivated by several if not all of these seven factors. The public and the publishers might not be sorry to lose an author motivated all

by one or all by another, but if you discourage all authors who like to see their names in print, or who like money or who have a hobby, there would be a dearth of books.

Perhaps it is safe to draw conclusions to this extent. First, is planning desirable? Planning based on the desires of teachers would be helpful in some ways. It could prevent an author from making a mistake about the actual demand for a book of a certain type. It could indicate preference regarding the less personal characteristics of the book: how long a book is acceptable; how many problems are wanted; what system of units is most popular; is it convenient that the notation agree with that of some other book? On the other hand, planning is dangerous if there is any tendency for it to stifle originality of ideas. Is there such a danger?

Second, is planning possible? Planning must operate on the author, and the question is: how will the good, bad, and indifferent authors react to it? Some of the authors' motives will respond to suggestion—some will resist. Will the good, bad, and indifferent authors respond in such a way that books will be better, planned than unplanned? I don't know the answer to that one. I have run out of conclusions, and I think I should like to leave these questions up to you.

Textbook Planning from the Point of View of Author and Editor

By W. L. EVERITT

Dean of Engineering, University of Illinois

As th size and complexity of any enterprise increases, planning becomes more and more important. This is necessary in all cooperative efforts, and engineering education is recognized as such a cooperative effort. While we may subscribe to the idea that Mark Hopkins on one end of a log and a student on the other would be the important elements of a university for a general education, modern technical education requires the utilization of many more facilities and aids. Nevertheless, we must continue to recognize that the character, ability and background of the teacher is *the* most important consideration.

In these days of emphasis on visual aids, let us remember that the most important, highly developed, and economical visual aids are books. They are a necessary part of the instructional system at the school and university level. However, if we accept the idea that the most important purpose of formal education is not to teach facts, but to develop in the student a confidence in his ability to learn and a method for continued development as he meets new situations, then we must prepare him to depend upon books in his post-school years for a lifetime of learning and vision. It is evident, therefore, that technical books should, and I believe do, serve a dual purpose:

1. as textbooks for residence courses where the material may be supplemented and developed by an instructor and
2. as reference books for self education.

It is true, however, that no typical individual exists who could speak in a representative manner for his group. It is in that very divergence of readers that the difficulty of satisfactory planning and coordination for the publication of textbooks lies. Any such planning which may be attempted will necessarily involve approximations and personal judgments. For the purpose of developing additional judgment and coordination, many publishers are making more and more use of technical consulting editors for definite but fairly broad fields, and it is this area area of planning that I was asked to represent on this panel.

Technical Area Conferences to Aid Authors

At times the need for the development of a new technical area by both courses and books becomes quite evident to a number of people. Under these conditions it may be possible to call a conference where representative outlines for a course may be worked out. Following such a conference, it is almost inevitable that one or more books will appear based upon the plans which were developed. Good examples of this occurred during the war. In the fall of 1941, a large group of us met at M. I. T. for a three weeks session to discuss the needs for instruction at the college senior level for Electrical Engineers on the principles of Ultra High Frequencies, as needed for the growing applications of radar. A surprising unanimity was attained in the development of course outlines and a supporting program of laboratory work. This immediately developed a need for a textbook, which in turn was justified

economically. The well-known book on Ultra-High-Frequency Techniques by Brainerd, Koehler, Reich and Woodruff resulted. In the winter of 1942 similar planning and development resulted in recognition of the need for the E.S.M.W.T. courses on Fundamentals of Radio. Several new books appeared to compete for this market. The series brought out by the Electrical Engineering Department at M. I. T. is another example of effective planning by the committee method to meet a definite objective.

Under ordinary conditions this committee procedure is only occasionally practical. There is not usually an unanimity on what is needed, there may not exist a definite sponsoring agency, and frankly, there would be difficulties in preparing a program that would avoid the dangers associated with the existence of financial and professional interests of authors, publishers and teachers. However, from time to time, as new areas of interest develop, for example, servomechanisms, or electronics for nonelectrical engineers, it might be well for this society or this section to consider setting up conferences to plan programs for appropriate courses. Such conferences might meet after or during the summer meeting of the society. As courses are developed, textbooks would not be long in appearing. In a free enterprise system I do not think it would be desirable for the sponsoring agency to designate the specific authors.

Spontanaity of Textbook Authorship

Becoming the author of a book is a spontaneous process. It is important that no planning process should hamper this spontaneity or the results will be drab and colorless. It is doubtful if many good books are produced by assignment. This is illustrated by the difficulty, especially during the war, of getting good technical manuals on manufactured equipment. Such manuals must be written, perhaps they are part of a contract, so someone is directed to write them. Even though the authors may be professionals, the resultant output is generally considered mediocre.

Since an author is self driven, he usually has a message, something he wants to tell the world about. I think this is desirable. It provides the sparkle that differentiates the interesting from the dull. The greater number of electrical engineering books are produced because the author is a teacher in fact or at heart who believes firmly that he can plan a course on, and tell his student more clearly about, his subject then anybody else. Hence, he starts to prepare a set of mimeograph notes to supplement the inadequacies he believes exist in available texts. These he may ultimately develop into a full fledged text. I believe this experimental process is a good one if the author really receives recognizes, accepts, and acts on the criticisms which this makes available. This criticism may appear in a number of forms. It may come from suggestions from students, from comments of colleagues using the material, or it may be in the form of the low grades of a class which has been examined on the material which the manuscript has been designed to elucidate.

Author's Responsibility

In the development of all human relationships the ability to put oneself in the other fellows place is one of the most important attributes. It is particularly important for the teacher to analyze his teaching from the standpoint of the student, for the author from the position of the reader. But it is technically difficult for an author to do this, the mere act of going over and over the manuscript, a necessary part of writing, makes it almost impossible not to overlook inadequacies in presentation. It is at this point that the technical editor may perform an important function. He should try to read the manuscript as though he were a student with only the preparation which the manuscript assumes. He must be watchful that the presentation is logical, and develops the subject smoothly without sudden changes in dif-

ficulty, and without requirements of supplementary knowledge which cannot be expected from the reader. He should recognize lack of clarity and call for improvements where needed.

New books should be really new and not a rehash of old material. It is true that the new part may be largely a new method of organization or presentation, but unless there is a real indication of originality I think there is a moral if not a legal responsibility on the author, editor and publisher not to develop a book just to introduce a name to the public. Some technical books have skated pretty close to plagiarism even if it could not be proven in court.

It is probable that this panel would not have been developed unless a need were felt for more voice in the production of books by the teacher. I have suggested the possibility of special conferences from time to time. I believe the development of the series idea provides an additional avenue for teachers to indicate to series editors what they want. This can be done by personal discussion or by correspondence. I can say that such suggestions would be welcomed, and I believe would produce desirable results. Series editors are individuals in your general field who can work with you in a personal manner. They in turn will have contacts with prospective and developing authors and can act as exchange centers.

It is hoped that this panel discussion will be a step forward in the planning of technical books. At the same time it should be recognized that we are the envy of the world not only on our technical developments, but also in the manner in which we have reduced those developments to the printed work so that they may be passed on to students, in both school and industry, and not only in the United States, but wherever the English language is read.

College Notes

Dr. Harry P. Hammond, dean of the School of Engineering at the **Pennsylvania State College**, will retire with emeritus rank on Sept. 1 and will be succeeded by Dr. Eric A. Walker, director of the Ordnance Research Laboratory and professor and head of the department of electrical engineering. The change was announced by Dr. Milton S. Eisenhower, president of the College. Dr. Walker, came to Penn State on July 1, 1945, from Harvard Underwater Sound Laboratory. For the past year, Dr. Walker has been on a leave of absence, acting as executive secretary of the Research and Development Board of the Department of Defense.

The Economic Advancement of Underdeveloped Areas[1]

By YALE BROZEN

Professor of Economics, Northwestern University

There is deep concern in the world today over the problem of underdeveloped areas. The "problem" is a different one, depending on who defines it, but the common aspect of all the different "problems" is the low level of per capita income in these areas. The United Nations report on *Technical Assistance for Economic Development* implies that the underdeveloped territories are those where resides "substantially more than half the world's population" and where average income per head is "less (often much less) than $100 per year" in contrast with an average income in the United States in 1947 of $1400.

The average per capita income in an area may be raised by action along three different lines. One is a reduction of the population (by birth control or by increase of the death rate or emigration in those classes of the population which have little productive capacity) relative to non-transportable resources, if industry and agriculture are not operating in the range of increasing average returns. A second line is through an increase in resources relative to the population (by importation or accumulation of capital). The third line is through improvements in the average technology practiced.

These measures increase the kind of income that can be measured against money—the usual statistical concept of income. An ever present danger in development programs is that the sacrifice of psychic income from non-pecuniary sources may exceed the gain in psychic income resulting from the increased production of the goods which bring pecuniary returns. The production of transferable goods (those that can be bought and sold) may increase at the expense of the production of non-transferable goods (love, stability, personal integration, etc.).

The Technological Level of Backward Areas

The Point Four program is aimed at the problem of raising the average level of technology practiced in underdeveloped areas. Average technology lags behind technological leaders who in turn lag behind technological possibilities. That these lags are greater than those dictated by economic considerations is not at all certain.[2] Usually, naive comparisons of average productivity per head in less developed regions with that in highly-developed regions are used to show what technology can do. This fails to take account, however, of the difference in resource patterns and, also, confuses the problem of technological advance with the problem of the capital supply.

[1] This paper was made possible by grants from the Rockefeller Foundation and the Technological Institute at Northwestern University. An expanded version will appear as a chapter in *The Economics of Technological Change* which will be published in 1952.

[2] See Yale Brozen, *Social Implications of Technological Change* (available on request from the Social Science Research Council, 230 Park Ave., New York 17, New York), Ch. 6 for a discussion of the distinctions between levels of technology and the lags dictated by economic considerations.

Even if capital were supplied on the same conditions as in highly developed areas, earnings possibilities may be inadequate to attract a sufficient supply of capital to raise the amount per head to the level prevailing in other areas. Aside from the question of the supply of labor skills or the institutional structure, the lack of earning prospects may be the consequence of the resource pattern. Technologies developed for an oil-coal-iron-waterpower-broadleaf-forest complex of resources are not easily transferable to tropical rain forest or semi-arid regions in which the primary source of power is wind and sun. Technological possibilities for such areas may be very low.

Rather than simply transfer our tools and techniques to the world's backward areas, a more economic procedure might be the development of an appropriate technology for those areas. A research and development program such as that which produced the designs for buses and trucks now used for desert runs in the Near East, together with the necessary new equipment, might be less costly than building a railroad. Such a program might make progress economically feasible where, with present techniques, it would be uneconomic.

Directions for research programs designed to raise the level of technological possibilities must be carefully chosen in terms of both the economic results that may flow from new techniques and the value consequences. If an area is the major producer of an internationally traded commodity for which demand is inelastic and to which its resources are specialized, improvement in output from given quantities of resources will cause the terms of trade to move very adversely with small increases in the rate of production. As a consequence, area income will fall. In these circumstances, research should be directed toward the development of alternative uses for the resources of the area rather than the improvement of present uses.

The value consequences of changed techniques of production must also be considered. If natives of an area prefer the values inherent in cottage industry to those inherent in factory industry, for example, research should be directed toward the improvement of techniques of cottage production.

The values inherent in cottage production of textiles have been recognized in legislation. The Province of Madras, India, prohibits the further expansion of textile mills. Such action has been undertaken because the values inherent in cottage industry are deemed to outweigh the value of extra product obtainable by reorganizing the industry along factory lines.

Appropriate Techniques and Industries for Under-Developed Regions

The selection of techniques to be used and industries to be developed in a region must be governed by the resource and market patterns of the area. If large amounts of capital are required to practice soil conserving farming, then such farming technique should not be practiced in regions with abundant soil and scarce capital.

Resource patterns of underdeveloped regions do not fall into any one type. Generally, the regions into which European immigrants poured were underpopulated with the consequence that land intensive techniques and industries were appropriate. Usually, capital was scarce in such regions, as well as manpower, which precluded capital intensive industry until much later stages of development when an indigenous capital supply began to accumulate to add to foreign sources. Technological possibilities were developed in the direction of both labor and capital-saving devices.

Many of the areas which concern us today have high population densities. Here, the appropriate techniques and industries are those which use much labor and relatively little land or capital. Where the skill of the labor force is low, the feasible techniques are those which require little skill intensity.

By introducing industry with a low skill requirement, the skill level of a labor force may be raised in the process of learning the low level skill required. This may be more economical than attempting to raise labor skill to the level required for a machine tool industry by the more direct means of a sufficiently long training period. By starting a textile industry, skill and textiles are produced as joint products at a cost lower than that of producing them separately.

The textile industry has been the great educator in industrial skills. It has typically developed in regions possessing little factory industry. In it, labor learned the requisite discipline and skills which then became a part of the environment. Industry using higher level skills could then develop, taking labor which had grown up in such an environment and educating it to a higher level as easily as the textile industry had educated it to a low level.

In regions where textile mills had been long established, industries requiring higher skills usually began bidding labor away from the textile mills. Costs of producing textiles in such regions rose, insofar as growth of skill did not succeed in encouraging the use of skill-intensive techniques in producing textiles. As costs went up, new regions possessing supplies of low skill labor found it economic to establish a textile industry. In the United States, for example, the textile mills of New England succumbed to the combined onslaught of the competition for its labor by the more skill-intensive industries and the competition for its markets by the new mills of the Carolina Piedmont. The Piedmont is suffering a similar fate as the mills of Mississippi grow.

It is not easy to judge what industry will be appropriate for an underdeveloped area by examining the resource combinations of those operating in better developed areas. Farming in the United States is capital and land intensive. This does not necessarily mean that farming is precluded in areas lacking capital and poor in land. Other techniques may be available which are not intensive in the scarce resources. Farm operation in some sections of the world uses techniques involving extreme labor intensity and very little capital and land. The little capital and land available is intensively worked and little of it is used per unit of product.

With techniques of this latter type, we would expect high yields per acre, although yields per man would be low. Yet, we sometimes find areas of scarce land are also areas of low yield relative to the yields in the United States and Europe. Here, it would seem, is a place where great improvements can easily be made by a change in practice with little addition of resources. By changing the strain used, crop yields may be increased. It is conservatively estimated that yields in the rice-producing countries could be increased by 10 per cent if the best varieties were generally utilized, while the introduction of hybrid varieties of corn can add 20 or 30 per cent to the crops. Some changes, such as fertilization and irrigation, may require additional capital. We might expect the additional capital to be extremely productive in these circumstances. Development in these cases requires, then, an increased capital supply, or at least diversion from other uses, as well as a rise in the average level of technology.

In almost every practical case, the problem of development involves a need for more capital if the better technique is to be put into operation. Since capital from abroad seldom amounts to more than a dribble, most areas must look to means of supplying their own capital. Essentially, this means they must either find ways to release resources from subsistence requirements or find ways of reducing consumption, assuming there are no large supplies invested in stores of value as in India.

A most fruitful method of acquiring resources for use in capital construction is that of raising the health of the population and releasing the millions of man-

days lost through illness. A dose of DDT costing little may produce man-days released from malarial confinements worth much. Water purification and sanitation measures may be similarly productive.

The underdeveloped area in the modern world need not concern itself with developing industry according to the priority of wants as long as interregional commodity flows are not barred. For it, resource patterns, technology, and markets are the appropriate determinants of its growth. It is more efficient to engage in a land-intensive industry such as iron ore mining in an underpopulated area like Labrador than it is to grow food. Foodstuffs can be obtained with less expenditure of resources, under the pattern of available techniques, by mining ore and trading with other areas. Food production may be increased, then, by ceasing its direct production.

Similarly, a backward area can develop a capital-intensive industry when it can compete with capital-rich industries of other areas for its capital rather than with capital-poor industries in its own area. To the extent that capital markets are imperfect, or that political or monetary instability or property insecurity prevails, this does not apply.

Finally, the sequence of industries and techniques used during a course of development will depend upon the relationship of external economies. As long as transport is crude, small-scale operations appropriate to a local market will prevail. The building of a bridge may connect markets (as in a recent instance in Liberia) and permit the growth of specialization and of large-scale, capital-intensive industry. The state of development of services such as transport, electric power, water supply, etc. is both consequence and determinant of industrial development.

As industry grows in an area, individual concerns can shed functions to their gain and contribute to the founding of separate and new industries which in turn may make further industrialization possible. As the fishing industry in tropical Monrovia grows, it may finally produce enough fish to supply immediate needs with enough left over to be quick-frozen for off-seasons and other markets. A refrigeration plant may then become economic, but it will have to produce its own power. Perhaps diesel or gasoline-engine driven compressors will serve it. As other concerns begin production, it may finally become economic to found a central electric power plant. The resultant cheapening of power may then lead to manufacturing or other operations which could not be undertaken if expensive self-produced power had to be used. A priority in the development of industry may be dictated, then, with those consuming little power or using an abundant domestic resource coming first. Those consuming much power without any offset through economies generated by use of an abundant local resource must wait until the advantage of external economies in the production of power makes their operation economic.

We have here three primary determinants of the developmental pattern. Resource oriented industries which can capitalize on some resource relatively more abundant in the area, and market oriented industries for whose produce a local market exists, are one element in the pattern. The second element in the pattern is the barriers between the area in question and others. High barriers dictate that priority of wants and local supplies of the kinds of resources (capital and skilled labor) that might otherwise immigrate must rule the developmental pattern. If no barriers exist, then only the non-transferable resources and transportation economies in supplying the local market, that is, the first set of determinants, will dominate. Finally, the time sequence of the developmental pattern is important. Industry using low level skills and suffering little from the lack of external economies should be founded first. Industries using high level skills and dependent on external economies can then follow.

False Issues in Development of Backward Areas

In the opening paragraphs, we warned against the application of Western standards to low income areas in judging whether or not a developmental program should be instituted. A society in which men prefer planting their sweet potatoes in a neighbor's field in order to have the pleasure of companionship is not to be lightly regarded as suffering from a lack of indoor plumbing. If leisure and aimless camaraderie are preferred to variety in adornment, frequent baths, and gasoline powered vehicles, then a proper measure of income may indicate a higher level per capita than that prevailing in "advanced" regions.

Many of the programs proposed for less-developed areas emphasize industrialization as a goal. The resource patterns found in some regions, however, will yield higher per capita incomes if used in agricultural pursuits or other non-industrial uses. The yearning for industrialization is rational for these areas only if we presume that their populations want to prepare for war or if this is the only method of inculcating new attitudes toward marriage and family size which will have desired effects on population density.

Even where industrialization is appropriate, there is often an unwarranted eagerness to develop heavy, large-scale industries. Industries such as steel, for example, are the late comers in any sequence of industrialization. Unless a large market, on the order of an annual demand for half-a-million tons, is available, and unless men skilled in organization have been trained and have a background of experience, a steel industry will prove uneconomic although all the necessary limestone, coal and ore may be present. For a balanced steel industry, a three million ton market is required. Respect must be paid to the necessity of following the sequences discussed above in industrializing an area.

If economic development requires the building up of extractive industries such as mining and lumbering, the cry is often raised that the area is exploited. Materials are being removed, is the complaint, that should be kept as a basis for domestic industry. Aside from any conservation issue, the deposit or timber stand involved simply represents a certain amount of capital in a specific form. If the natives of any area are able to convert this capital into other forms by selling the specific capital items, they will be able to obtain other kinds of capital embodied in the form of trucks, pumps, tools, and similar items which can contribute more to increasing the productivity of their labor than idle capital in the form of undeveloped natural resources. If the native population chooses to dissave, that is, to use the proceeds from the sale of capital items to increase their consumption, this surely is a decision they are entitled to make.

Usually, the question of exploitation can be validly raised only when land tenure systems are such as to permit foreigners to dispossess native owners without adequate compensation for the property involved. The charge of such action can be leveled with merit against many colonial administrations. This, however, is a question of property rights rather than a question of the type of industry appropriate for the region in question.

In some areas, there is a fear that permitting foreigners to withdraw the earnings on their capital is exploitative. Investment by foreigners increases production. The private returns to foreign investors will be less than the increase in production. By permitting withdrawal of profits, natives will find that investment will be made by foreigners that would otherwise be blocked, and that native living standards will rise since even complete withdrawal of private earnings by foreigners will leave the area economy with a net increase in supplies of goods. This will be true, if for no other reasons, because natives will not

take jobs in enterprises started by foreigners unless the jobs pay as well as or better than those they leave, assuming no preferential treatment is used to force natives into such position (such as the head tax and hut tax widely used in Africa).

The capital supply is a problem often raised in discussions of area development. It is absurd to presume that the United States can supply more than a dribble of capital to other areas. The five billion dollar a year Marshall Plan was only a drop in the European bucket, largely useful as an incentive to Europeans to re-order their economy, yet it was one of the causes of inflationary pressure in the United States. In the total world situation the few billions the United States can afford each year can do little more than provide for technological leaders.

Native capital must furnish the long run base for development programs. At present, much of the native capital that might be available is grossly misdirected because social institutions inhibit productive use of it. Natives who might devise or institute new techniques, develop enterprises, or furnish the capital for such projects fail to do so because of arbitrary tax laws, discriminatory procedures used by colonial administrations, indefinite property tenure systems, leases which afford no motivation for economic use of land, lack of knowledge of possibilities, political arrangements such that the return to efforts directed toward obtaining power is greater than the return to developmental efforts, and a host of related reasons.

Another issue raised in connection with the role of the United States is the effect of development abroad on the U. S. economy and the living standards of its workers. If foreign industry develops with the use of low-paid labor, will we not have to raise our tariff barriers or suffer lower living standards? Any elementary economics textbook can answer this question and does answer it with an emphatic "No!" By wiping out the involved, cumbersome U. S. customs procedures and permitting free entry of goods, we can aid development in the underdeveloped areas and *raise* our living standards. Our workers will find relatively more productive job opportunities opening up for them and the international division of labor will increase world production with the consequence that there will be more goods for U. S. nationals as well as for foreigners. Foreign living standards will rise, but not at our expense. Our living standards will rise as well.

Finally, we must warn again against judging the appropriateness of an industry for a particular area by the form of its technical organization in a developed area. Modern textile industry in advanced areas uses large quantities of capital and little unskilled labor. Despite the lack of capital and abundance of unskilled labor in less-developed sections, it may pay to introduce textile industry. The techniques employed, however, should not be those common to advanced areas but, instead, those which make use of the resources abundant in the area in question and minimize the use of its scarce resources. American engineers aiding such developments will be less often accused of uneconomic "over-design" of installations if they stop slavishly imitating the techniques they have seen used in their own country.

Engineering Norms for the Iowa Chemistry Aptitude Test, Form M

By WILLIAM C. KRATHWOHL

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In the manual for the Iowa Placement Examinations, Form M, separate sets of norms are given for engineering and liberal arts students for the mathematics and physics aptitude tests, but only one set of general norms is given for the chemistry aptitude test. Since the mathematics and physics aptitude norms for engineering students differ markedly from those for liberal arts students, it was felt that there might also be a similar difference for the chemistry aptitude test. Such has been found to be the case in this instance. These norms for engineering students should be particularly valuable to high school counselors for use with students who plan to enter the engineering profession.

TABLE I

ENTERING FRESHMAN ENGINEERING STUDENT NORMS FOR THE IOWA CHEMISTRY APTITUDE TEST, FORM M

Percentile Ranks	Raw Scores	Percentile Ranks	Raw Scores
99	122	50	95
95	117	45	92
90	113	40	90
85	109	35	88
80	107	30	86
75	104	25	83
70	102	20	80
65	100	15	77
60	98	10	73
55	97	5	63
		1	46

The norms for the Iowa Chemistry Aptitude Test, Form M which are given here for entering engineering students are based on 675 engineering students at the Illinois Institute of Technology, who entered between September 1948 and February 1950 and who had complete records. These 675 students are classified into the following engineering groups: 222 mechanical, 203 electrical, 136 chemical and metallurgical, 82 civil and 32 industrial.

The chemistry aptitude norms for these students are contained in Table I.
The statistical constants for these norms are: mean $= 92.8$, sigma $= 15.6$, and median $= 94.6$.

In order to get an idea of the kind of students who constitute this group, statistical constants for them are given in Table II, for the 1945 edition of the American Council on Education Psychological Examination, and also for the Bennett-Fry Test of Mechanical Comprehension, Form BB. The psychological examination was used to indicate something of the mental ability of the students being tested, and the mechanical comprehension test was used to compare the entering freshmen group with the group who entered with advanced standing.

These scores give evidence that the group has some of the typical characteristics of engineering students. For instance, the mean of their total scores is higher than that of the average liberal arts student and likewise their performance on the Q parts of the test is much

higher than on the L sections. The mechanical comprehension data show that the group, as far as this test is concerned, is typical of engineering freshmen.

Norms on the Iowa Chemistry Aptitude Test, Form M, for engineering students who entered with advanced standing, are given for two reasons. (1) Students entering with advanced standing should have a higher performance on an aptitude test than do freshmen, because there is a certain amount of learning connected with most written aptitude tests, and because most students with advanced standing have already undergone a screening effect in their freshmen year which eliminates the less able students. (2) Admission officers nowadays are faced with the problem of admitting more students with advanced standing in comparison with freshmen than they formerly did. This problem has arisen because of the increased number of junior colleges which, with comparatively lower tuition fees, attract students to complete one or two years at those schools before entering the technical college of their final choice.

Table III gives the norms for the Iowa Chemistry Aptitude Test, Form M for advanced engineering students. These norms are based on 532 students who entered the Illinois Institute of Technology with advanced credits and who had complete records between September 1948 and February 1950. The students are classified into the following engineering groups: 169 mechanical, 160 electrical, 84 chemical and metallurgical, 63 civil, and 56 industrial.

TABLE III

ADVANCED ENGINEERING STUDENT NORMS FOR THE IOWA CHEMISTRY APTITUDE TEST, FORM M

Percentile Ranks	Raw Scores	Percentile Ranks	Raw Scores
99	127	50	107
95	122	45	106
90	120	40	105
85	118	35	103
80	117	30	101
75	115	25	98
70	113	20	96
65	112	15	93
60	110	10	89
55	109	5	83
		1	73

The statistical constants for these norms are: mean = 105.9, sigma = 12.1, and median = 107.4.

In order to get an idea of the kind of students who constitute this group, statistical constants for them are given in Table IV for the Ohio Psychological Examination, Form 22, the Iowa Physics Aptitude Test, Form M, and the Bennett-Fry Test of Mechanical Comprehension, Form BB.

The fact that the national percentile rank on the Ohio Psychological Examination is not higher than 51 is probably due

TABLE II

STATISTICAL CONSTANTS FOR THE ENTERING FRESHMAN GROUP

Tests	Mean	Sigma	Median	Percentile Equivalent	For Comparison Group
A.C.E. Psychological Examination					
Total Score	118.9	19.2	118.7	75	College Freshman
L Score	69.0	14.3	68.9	65	College Freshman
Q Score	49.7	8.2	49.9	84	College Freshman
Bennett Mechanical Comprehension—BB	37.5	10.0	38.2	46	Engineering Freshman

TABLE IV

STATISTICAL CONSTANTS FOR THE ADVANCED STANDING GROUP

	Mean	Sigma	Median	Percentile Equivalent	For Comparison Group
Ohio Psychological Examination, Form 22	90.0	22.1	89.2	51	College Freshman
Iowa Physics Aptitude, M	65.2	11.1	64.9	60	Engineering Freshman
Bennett Mechanical Comprehension, Form BB	41.3	9.1	42.3	62	Engineering Freshman

to the verbal nature of this test. Engineering students seldom do as well on verbal tests as they do on tests involving quantitative or abstract material.

As was expected, the percentile ranks for the medians for the Physics Aptitude Test and the Mechanical Comprehension Test are above those for entering freshmen.

The mean percentile rank on the Mechanical Comprehension Test for advanced students is higher than that for the entering freshmen, probably because of the screening effect of the first year or two in an engineering school.

In order to discover the degree of advancement of these students, an average was found of the highest course in mathematics which had been offered for entrance. If college algebra is counted as 1, analytical geometry as 2, differential calculus as 3, integral calculus as 4, and differential equations as 5, the average highest course was found to be 3.01. This number shows that the average advanced student has had at least differential calculus before entering, which places the average of the group at not less than the middle of the sophomore year. Just how much more advanced the average of the group is cannot be estimated from this data, since there usually is no required mathematics for the junior and senior year.

It is hoped that the use of these norms will be of help to counselors and advisors in giving a clearer picture of the chemistry aptitude of an engineering student than if such a student were compared with a group of general freshmen.

An inspection of the national percentiles of the medians for the various tests indicates the necessity for differentiating between engineering students and students in general. It also suggests the advisability of establishing norms for different years in an engineering school. Such a set of norms should prove to be useful, particularly in our present state of national emergency.

College Notes

President Dawson was honored by receiving the Doctor of Engineering Degree, Honoris Causae, from the University of Syracuse and Nova Scotia Technical College. He delivered the principal address at the anniversary celebration of the L. C. Smith School of Applied Science at Syracuse University and also at the graduation of the Nova Scotia Technical College. Throughout the year, President Dawson has visited many of the ASEE Section Meetings, including those of the Southwestern Section, the Rocky Mountain Section, the North Mid-West Section, the Michigan Section, and the Missouri Section. He has also attended meetings of the ECPD, the Division of Relations With Industry, and other group meetings involving ASEE participation.

Photoelasticity: A Powerful Educational Tool

By EVERETT CHAPMAN

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Photoelasticity, as an educational tool, has several strong appeals.

It is an exact method. Certain materials exhibit double refraction when strained and the theory has a mathematically exact correspondence with the elastic theory of stress distribution. Thus, the method will quantitatively check the results of simple analysis and will reach far beyond into problems whose boundary conditions make them all but impossible of solution.

For example, much fruitful work is to be done in the untouched field of stress relieving curves. The sophisticated designer has been taught to incorporate generous radii at abrupt changes of boundary contour—but he still puts in segments of circles because he has a compass. The author has found that elliptical blending curves are much more effective than circular radii in preventing bursting of turbosupercharger wheels. Other curves may be even more effective.

The most powerful educational advantage, however, lies in the tremendous eye-appeal of the method. The visual impact of a photoelastic image drives home the fundamentals of sculptured design for fatigue-tough structures as no other method can do. No other method so quickly emphasizes the importance of stress distribution in so colorful a manner. The entire stress pattern, the local "hot spots" in the design where failure will initiate are presented to the student either in all the colors of the rainbow or with the detail of a fine etching and the brilliance of mathematical perfection.

Photoelasticity does not measure the properties of materials: it does measure the relative values of the stress from point to point within the boundaries of a strained shape—hence the picture of "stress distribution" and the arresting emphasis on the "hot spots" where failure will initiate.

The theory can be simply stated. Certain materials exhibit double refraction when strained—the amount of double refraction is proportional to maximum shear stress. This is the basis of the exact one-to-one correspondence of the photoelastic image and the mathematical behavior of any strained elastic body.

It only remains to examine the degree and distribution of double refraction to get the complete picture of the stress distribution. Note that the image depends only on the shape of the model and the manner of loading. This is the great short cut through tedious mathematical methods where boundary conditions in complicated shapes severely limit quick analysis. Cut any shape the imagination can conceive: load it in any manner you wish: the picture is correct and easily interpreted. Prove the simple case of two point bending and reach out from there.

Double refraction results in interference phenomena when examined under polarized light and this is the basis for the optical set-up used to examine the stress pattern.

Color Patterns and Stress Distributions

When using white light, having a continuous spectral distribution for illumination, one frequency will be cancelled out by interference at each point of constant double refraction (constant maximum shear) leaving a brilliant color which is white light minus one frequency.

The colors do not appear in the usual rainbow sequence: they are brilliant and arresting.

These are the isochromatic lines—lines of constant color—lines of constant maximum shear.

The first color appears at the point where the structure will fail and will repeat itself as the load is increased until the "hot spot" is surely marked for attention. The remainder of the structure assumes the characteristic hues in a lazy manner, showing that generally the material is not working very hard; while the "hot spots" painfully assume most of the burden.

Such a demonstration never fails to open a world of feeling and speculation to the young student or engineer who may have wondered how far P/A and Mc/I can take him in the field of aircraft structures, for example, where every pound of material must do its utmost without failure.

When using monochromatic light where only one frequency is present, the image has the detail of a fine etching and the brilliance of mathematical perfection. The 5460Å line in the mercury spectrum is a popular source of monochromatic light since the line is brilliant and excellent filters are available for isolating it. Monochromatic illumination at a single frequency is cancelled out by the double refraction: so there are no gradations of color to keep track of—the image is a series of black and green lines—exquisite in detail and sharpness. If these lines of constant maximum shear are sketched or photographed, one immediately has a contour map of a "rugged terrain" whose altitude at any point equals maximum shear.

Another interference phenomena, best exhibited under white light, occurs where the principle stresses are parallel to the plane of polarization of the polariscope. Thus, with plane polarized white light, black lines will be superimposed on the brilliant colors. These black lines are the locus of all stresses parallel to the plane of polarization.

Sketch these black areas, noting the plane of polarization: shift the plane of polarization a few degrees and sketch the new locations of these black areas: repeat. Such a procedure, taken through 90 degrees produces a map of the stress trajectories: the flow of stresses in the strained shape is immediately apparent.

These are the isoclinic lines—lines of constant stress inclination.

There are two considerations that prevent photoelasticity from being king of all experimental methods in simplicity, speed, and comprehensiveness. Neither of these considerations are blank wall limitations: in fact, surmounting them only appears complicated by contrast with the utter simplicity of what has gone before.

First: While the isochromatic lines (lines of constant maximum shear, which is $(p\text{-}q)/2$,) and the isoclinics (lines of constant stress orientation) can be sketched in a few minutes, the separation of the p and q stresses from the $(p\text{-}q)/2$ information takes longer. There are several methods of effecting this separation which are treated in the standard texts on the subject.

In this connection, the author would like to make a practical point. It is not necessary to separate p and q stresses at the boundary, since the normal component q vanishes at the boundary. Hence, the value of the isochromatic line where it intersects the boundary is the value of the tangential stress at that intersection.

The boundary stresses can be read with the utmost ease. Since most of the trouble with a structure occurs at the boundary, it seems to the writer that enunciation of p and q stresses in the body of the specimen has more academic than practical interest.

Second: While the method is fast, easy, and direct in two dimensions (models can be cut from flat plastic in ten minutes from the template), the technique of three dimensional photoelasticity is more difficult and painstaking by contrast.

The method consists of "freezing" the stress pattern in a lumpy piece of plastic whose shape is under investigation: then slicing the model on appropriate planes. Slicing does not disturb the stress pattern if done carefully. After polishing to constant thickness, the slices are examined as a two dimensional specimen with the same ease as before. The author, in several investigations, has used this method and is not impressed by the alleged "difficulties" of three dimensional photoelasticity.

Educationally, from where the teacher-student sit, all the feeling for flow of stresses, the necessity for blended sculptural design, and solutions of many important plane stress problems are quickly and easily apparent from two dimensional studies. There is no dearth of interesting and fruitful cases in two dimensions. Suffice for the student to know that excursions into the three dimensions follow exactly the same principles at the price of a little more work.

The requirements of a photoelastic laboratory are simple and inexpensive.

Model Making

Sir David Brewster enunciated the principle of "forced double refraction in glass" before the Royal Society in 1816.

The succeeding struggles of those who satisfied their intrigue with the method by working in glass certainly erected some sort of monument to scientific curiosity. Mesnager studied a complete arched bridge made of glass in 1916.

Glass is many times more difficult to work than some of the available plastics and these easily worked materials are many times more sensitive for "forced double refraction." Models will occasionally break. In glass, it must have been a catastrophe: in plastic, the author's technique has a new model ready in ten minutes.

The best all around plastic is known as CR-39. CR-39 is available in flat sheets whose polished surfaces are entirely adequate. It is very inexpensive compared to others, has negligible ageing, and can be easily machined with strain free edges.

The essence of producing a strain-free edge is to cut the edge: it must not be rubbed. Edge stresses are heat stresses resulting from rubbing by dull tools or improperly ground tools. The writer has found that a ¼" diameter tungsten carbide cutter with 48 teeth, running at 20,000 rpm, cuts CR-39 and does not rub it. Very light cuts are taken at quite fast feeds. Tungsten carbide stays sharp and maintains its cutting edge on CR-39. Other materials dull quickly.

A sturdy template is prepared from ".100 brass or aluminum of the desired shape and the plastic sheet is scribed from this template leaving about ½2nd inch all around. This does not have to be too accurate. The model is sawed from the sheet using a high speed vibratory jig saw with short rapid strokes. The plastic, fastened to the template, is guided against the high speed cutter in two cuts, a roughing and finishing cut. Only ".005 is taken off at the last cut. The template is not mutilated and is thus available for a series of models or quick replacement in case of breakage of the model. Using a nicely aligned spindle and work table, strain-free square-edged specimens can be made in ten minutes from the template.

Loading the Model

The loading frame should be equipped with shackles, pins, etc. so that tension, bending and compression may be imposed on a model. The guillotine type of loading frame is the most versatile.

The loading mechanism should be arranged to gently load and unload the model while the image is being examined. In this way, the first lines to appear can be identified and proper values assigned to succeeding lines. The manner in which the stress pattern builds up is the key to reading the stress distribution, the location of the "hot spots," the points of contraflexure, and the socalled isotropic

points which are the areas where the principle stresses are either finite and equal or equal to zero. From elastic principles, no stress can exist in a corner whose angle within the model is less than 180 degrees. Hence, such points are landmarks of known zero stress from which values can be assigned to adjacent lines. A student can learn to read the pattern as it forms in about ten minutes, once the pertinent features are pointed out to him.

The essence of fast interpretation is to have controls of the load right at the viewing station, so the load can be changed while the model image is being studied.

It is helpful to have the loading mechanism adapted for slow loading by means of sand, lead shot, or water. Movies of the build up of the stress pattern taken under such loading conditions can be striking when shown to a large group.

The Polariscope

The polariscope should be equipped with both white light and a mercury vapor lamp provided with suitable filters for isolating the 5460Å line. This is a good line because it is brilliant, the available filters are good and it is good photographically. The two light sources should be mounted so that either may be quickly selected.

It is essential that the model be illuminated by a beam of parallel light. If the light through the model is not parallel, false readings will result; because the interference phenomena on which the method depends, has the thickness of the model as a parameter. Thus, non-parallel light travels a longer path through the model than a parallel beam and results in false data. For the same reason, the square-edged specimen discussed under model making is essential if boundary stresses are to be accurately read.

Aspheric lenses having parabolic surfaces are excellent for producing maximum intensity beams of parallel light, since such a figure can be made to work at small F numbers.

Polaroid, preferably in glass, is the best means for producing a large aperture beam of polarized light.

Quarter wave plates are essential to a working polariscope. They take out the isoclinics (lines of constant stress orientation) so that the constant shear lines are uncontaminated while the stress field is being evaluated. They should be mounted so that they may be used either in the crossed or parallel position. The crossed position results in a dark field background, while the parallel position reverses all lines and gives a bright field background. This is useful in boundary stress evaluation since it seems easier with a bright field to locate the exact point of intersection of a given line with the boundary of the model.

A collimating lens then brings the parallel beam into an image forming lens.

A most convenient sketching arrangement is provided by incorporating a prism at this lens station so that the image of the specimen is projected downward on a sketch pad rather than horizontally onto the conventional screen. Manually sketching the lines of the phenomena augments the visual impact. Educationally, this is of extreme importance in fixing the content in the student's mind.

The polarizer and analyzer should be synchronized together in the crossed position and rotatably mounted so the plane of polarization can be varied at the sketching station without the inevitable distraction that accompanies fussy adjustments with each unit, reading the corresponding angles and making sure the two are always crossed as the plane is changed. Thus, the attention can be focussed on the main event.

To summarize the educational advantages of the photoelastic method as an adjunct to courses in strength of materials and structures:

(1) The method is exact and quantitative.

(2) The method has no limitations as to complexity of shapes that may be evaluated.

(3) Simple, versatile techniques and apparatus are available.

(4) Use of the method develops feelings for the flow of stress in a structure, emphasizes the need for sculptured design, points up the origin of fatigue failures, and, in particular, makes the student wary of the "sharp corner" trap into which so many designers have fallen.

(5) The method has tremendous eye-appeal which can be augmented by the manual exercise of sketching.

In the News

The following letter was sent by Engineering Manpower Commission to Senator Richard B. Russell, Chairman of the Senate Armed Services Committee, and Representative Carl Vinson, Chairman of the House Armed Services Committee, on April 25. The information therein was also furnished to General George C. Marshall, Secretary of Defense.

"The Engineering Manpower Commission, formed by six leading professional engineering societies having a combined membership of 140 thousand engineers, is concerned over the shortage of engineers available to the Armed Forces and to civilian activities essential to the country in the present emergency. In view of such shortage, the Commission is urging the necessity of conservation of the important resource of men trained and experienced in engineering to the end that a balance of supply be maintained between these components needing such specialized personnel. We are further urging that such personnel be employed so far as possible in ways utilizing to a maximum degree the training and experience they possess. The Commission recognizes that there is no group in our country that may substitute for the engineers. This makes more compelling the need for wise and efficient deployment of the service they are willing and eager to render.

"A very large number of engineers now holding some form of reserve status are engaged in civilian occupations vital to our security and welfare. Thus the utilization of the talents of these men effects both civilian and military necessities. It is the belief of the Commission that proper use of these necessary specialized personnel cannot be insured if decisions on individuals be made by persons who reflect one category of need primarily, but that both civilian and military needs must be met from the limited supply through joint decision of civilian and military agencies.

"The Commission, therefore, by unanimous action at its meeting on April 24, 1951 endorsed the provision of the Bill S.1 as amended and printed on April 17, 1951 beginning with line 23, page 55 to form 'one or more civilian reserve deferment appeal boards' to deal with the calling of reservists. It is suggested that military representation might properly be included on such board or boards, and that to give effect to such participation, the word 'who' in line 3, page 56, be replaced by 'a majority of whom.' A similar board should be created and charged with the coordination of regional boards. The Commission otherwise endorses the provisions for the boards of the amended bill from line 23, page 55, including line 2 page 57."

Respectfully submitted,

ENGINEERING MANPOWER COMMISSION
CAREY H. BROWN, *Chairman*

Drafting Problems Encountered in Structural Steel Fabrication

By R. M. SHERMAN

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The title of this paper "Drafting Problems Encountered in Structural Steel Fabrication" lends itself to more than one interpretation as to the context of this writing. I shall treat this subject from the standpoint of the drafting department of a structural steel fabricator considered as a definite unit of the business and shall discuss the many problems involved in the operation of this unit. In preparing this paper, I want to acknowledge the helpful advice and council of Mr. M. R. Van Valkenburgh, whose many years of experience in this field have made him a recognized authority.

Since structural steel in its final fabricated form is almost invariably incorporated in structures wherein public safety or public health is involved, it becomes necessary to provide that its design, fabrication and erection be done by or supervised by Professional Engineers. All forty-eight States have statutes which generally place this responsibility in the hands of Registered Professional Engineers. In this three-step process of design, fabrication and erection, the structural steel fabricator holds a key position. It is his responsibility to faithfully carry out the requirements of the design drawings through his own processes, which substantially consist of two steps; the making of shop details and actual shop fabrication. For fear of over-simplification of this process, let it be stated that the entire structure of a structural steel fabricators organization is complex and intricate, requiring major financing, much experience and the application of professional knowledge and special skills.

The purpose of the preceeding observations is to place the making of shop details—the drafting department in this organization—in its proper and vitally important place in this process of design, fabrication and erection of structural steel. In its own organization, the drafting department, to quote from the recent handbook on Structural Shop Drafting published by the American Institute of Steel Construction, is "the hub around which all operations turn."

The one purpose of the drafting department is to interpret intelligently plans and designs prepared by practicing Professional Engineers and to convey these interpretations into structural shop details which, when used to process structural steel shapes, will result in a structure which will be a faithful reproduction in steel of the designing Engineers plans.

Organization of the Drafting Department

The conventional organization usually consists of a Chief Engineer, a Chief Draftsman, checkers and detailers, wherein the Chief Engineer is the general executive director of the drafting department as well as the Engineering Executive for the entire organization, with the Chief Draftsman in direct charge of the management of the drafting department and scheduling the work so that orders are processed in the proper sequence and in such a manner that the talents of his men are used to the best advantage.

* Presented at the Mid-Winter Meeting of the Engineering Drawing Division, ASEE, Texas A. & M. College, January 19, 1951.

It is under the direction of the Chief Draftsman that all shop details are made and it naturally follows that he is responsible for the accuracy of the drawings, maintaining of standard procedures, and the solution of technical and mathematical problems.

It would appear that a drafting department, to operate with the most efficiency, should be manned by Engineering graduates with years of experience. However, from an overall standpoint, the tasks to be performed vary from the most menial and relatively simple to the most intricate and involved, and therefore, under professional supervision, it is possible from a standpoint of economy to use men of lesser education and experience in the lower bracket and men of more experience and education in the upper bracket. One of the problems of a drafting department is proper balance of experience to inexperience and a balance in the various levels of education.

It would be possible to operate a sizeable structural drafting department composed of draftsmen whose education extended very little past high school, provided the experience factor was in the proper proportion, but very few fabricators would want such an organization. Structural steel is purely an engineered product and one of the most important points of control, the preparing of shop details, cannot be entrusted entirely to the layman. Therefore it becomes necessary to have in the drafting department organization a sufficient number of key personnel who are Professional Engineers and who have sufficient experience to give them an easy and ready knowledge concerning the engineering plans with which the department is working. These men are usually assistants to the Chief Draftsman or are checkers or squad leaders.

The importance of engineering knowledge and experience in the drafting department cannot be overestimated, for it is easily possible for serious weaknesses in the finished structure to develop through ignorance of engineering principles while the shop drawings are being made. It is true that it is customary for the designing Engineer to check the shop drawings upon completion to see that all connections are safe and that all framing is handled properly before the drawings are placed in the shop for fabrication. Such checking, however, is a tedious chore, and many designing Engineers only give the drawings a rather rough check and rely upon the fabricator to have a drafting department of high enough professional level to eliminate connection and framing errors and at the same time possibly catch some errors the Engineer himself might have made. Such practices are probably frowned upon by the elite in the Consulting Engineering field who operate large organizations, but still a large number of smaller operators to some extent rely upon the professional knowledge and integrity of the steel fabricator.

Since the steel fabricating business as an industry is solidly founded and relatively free of "in and outers," most fabricators have built their drafting departments along such lines that they are capable of assuming the responsibilities just described. The exceptions are small shops which have sprung up with the advent and universal use of electric arc welding wherein the equipment needed if the projects are chosen for the purpose is hardly more than acetylene torches and electric welding machines. This is not at all intended to be a criticism of these processes but shops capable of fabricating only by these methods have a relatively small financial investment and have generally been operated without professional services. If the element of engineering is eliminated, such organizations are wholly incapable of being entrusted with the fabrication of structural steel.

Drafting Practice as Preparation for Consulting Engineering

In order to maintain such an organization, many steel fabricators follow the practice of employing young College graduates just out of school to begin

work in their drafting departments. Experience and the normal turnover in personnel which occurs in any organization generally allow these men to advance to positions of responsibility in a few years. At the same time, it is generally necessary to employ young men of lesser educational background who generally come under the direction and supervision of the Professional Engineers in the organization. Engineering graduates who eventually intend to go into the Consulting field can find no better background for their future professional life than a number of years in the drafting department of a structural steel fabricator. One consulting Engineer known to me, who maintains a sizable organization, will not employ a young engineering graduate unless he has served several years with a structural steel fabricator, and this point is made to further emphasize the existence of engineering practice, responsibilities and atmosphere that exist in the making of shop drawings.

The structural steel fabricator does not object too strenously to providing a training field for engineering graduates who intend to go into Consulting Engineering work and other allied fields provided he can have these men long enough to recover some of the investment he puts into them during the first year or year-and-one-half of their employment. It is difficult to set a time limit which differentiates between inexperience and experience in the field of structural drafting and naturally opinions vary. However, it is generally felt by many steel fabricators that a college graduate after one years employment is then ready to absorb good solid experience at a rapid rate and could be considered an experienced detailer at the end of two or three years when under the supervision of Engineers who have been in the business a considerable length of time. For the non-college graduate, the time schedule would have to be multiplied by two or three plus outside study, and such personnel would generally not be capable of rising above a certain level. Heads of Engineering Departments in colleges and universities sometimes advise their students in structural design to get their first experience with a steel fabricating company. I know of one individual in this capacity who has followed this practice for many years.

Training Problems

In training engineering graduates, the fabricator is confronted with a number of problems. One of them which is almost immediate is to eliminate from the mind of the new employee any idea that he is expected to know anything about the steel fabricating business in general or about structural drafting in particular. I have found that it is a good idea to advise him that his engineering degree is evidence enough that he has studied and has been found proficient in the basic courses of mathematics, physics, mechanics and the basic courses of his engineering major. It is also well to advise him that these courses comprise his formal education and that the fabricator is not equipped to carry these on any further on a formal basis, but that his education has given him the capacity to properly absorb and benefit by the experiences which will come to him.

A surprisingly large number of graduates will become discouraged and change to some other field if they are not given assurance such as described, that their inability to produce immediately after graduation is natural and expected. As an overall average, a young engineering graduate can be expected to turn out structural shop drawings profitably at the end of one year. Even so, he would be limited in the type of detailing he could do. If the work of the fabricator with whom he is connected is of a general nature and covers most types of structures, he can be expected to become rather expert at the end of four or five years. To the uninitated, it does not seem reasonable that so much time should be required, but as pointed out earlier, the steel business is of a complex nature and in order to reach mature experience,

it is necessary to absorb many intangibles in addition to mastering the concrete operations. Although I am sure that the engineering schools endeavor to teach their engineering students something about the steel business as a whole, I still run into graduates now and then who do not have a very clear conception as to the difference between a steel fabricator and a steel mill. Of course, misconceptions such as this might be corrected by a word or two, but there are literally hundreds of such situations and minutiae where only time and experience can give to a person a quick and easy knowledge.

Field trips in the senior year in college are a great help in fixing in the students mind the results of engineering practice and in its contribution to society, but it is equally important that these trips be planned very carefully. The time alloted to these trips, from my observation, is usually short and as a result, plant or project visitation is hurried and somewhat ineffective. Plant or project officials are usually willing and cooperative in giving their time to these field inspection trips, but I know of several individuals including myself, who have felt that the hurried atmosphere caused by a crowded and tight time schedule, did not permit a thorough briefing on the project or process and as a result, the knowledge gained was too cursory to be of much value. It is of great interest to structural engineering students to see engineering structures in the process of building, but since steel is the basic material with which a structural engineer works, I feel that it is most important that a structural engineering major have in his field inspection schedule an unhurried trip through a steel mill to see where and how steel is made into usable shapes, and then go through a steel fabricating shop including the drafting department, spending enough time to actually see how these shapes are made into usable structures. I feel that such inspection trips as just described are actually more important to the structural engineering student who does not intend to work for a structural steel fabricator, for if he does not avail himself of this opportunity while in engineering school, the chances are that he will not do so later.

In starting an engineering graduate in structural drafting, one of the problems is to each him to read engineering and architectural plans. Unfortunately this cannot be done in three easy lessons, and as a matter of fact, this might be the crux of the whole matter of structural drafting, for if a person can interpret accurately and in detail engineering and architectural plans, it is much less difficult for him to convert these interpretations into shop drawings. Some of the most costly errors made on shop drawings and not discovered until the steel erector has endeavored to put the steel together on the job, have been caused by a misinterpretation of the engineering plans. Sometimes this is carelessness on the part of several people, but many times it is due to ignorance of plans. Mark Twain is said to have remarked that "a man endowed with ignorance and self-confidence is sure of success." This of course was said facetiously and may even have some degree of truth for some lines of endeavor, but in structural drafting such a philosophy is certainly false. In fact, ignorance or inexperience will come out quickly in the drafting room, and the man who tries to bluff his way will be caught before sunset.

Starting at the beginning of an engineering education, the foundation of reading plans and making understandable drawings is laid. I speak of such courses as engineering drawing, descriptive geometry and the basic courses in mathematics. Often these courses are touched upon only lightly during the remainder of an engineering curriculum and as a result are largely forgotten by the student by the time he graduates, only to suddenly find upon obtaining employment, that the ghost he rid himself of many years before has miraculously come to life again. I know that educators are hard put to squeeze into four years the

bare necessities of an engineering education, but some means should be found to keep fresh these basic courses.

Employing Graduates

A steel fabricator has a problem when it comes to interviewing with reference to employment a young man who is about to graduate. I have interviewed many of these students, who at the time of the interview were finishing their senior year and were involved in intricate engineering problems which later would only be entrusted to those of long experience. I am then confronted with the unpleasant task of informing them that to begin in the steel busines it is necessary to go back four years and take up drafting again. I am serious when I say that this comes as a shock to four out of five students, and more often than not causes the student to search in other fields for employment. Some people consider drafting one of the menial tasks of engineering and if followed without professional knowledge, the person may be no more than a stenographer of the drafting board, merely putting down what others dictate. If this be true, it must be stated, however, that such dictation is not done orally, but is transmitted through drawings, and I submit to you that an engineer who cannot express himself through intelligent and legible drawings is in no better position than a doctor who could not put down in writing one of his prescriptions for others to fill, but would have to go to the drugstore and mix it himself.

In training for structural drafting, the best teacher is experience although books of standards and outside reading are aids. One of the most prevalent shortcomings in individuals in this work centers around those things taught in descriptive geometry and similar courses. The Encyclopaedia Britannica is dissertating on the subject of descriptive geometry states that "it is the means by which the designer conveys his ideas to the builder or mechanic, and has been called the universal language of the engineer." Further than that, it tends to develop in an individual a sense of perception which makes it possible for him to from and visualize in his mind three dimensional objects taken from what he sees drawn on two dimensional paper. Some people have this ability as a natural aptitude and others have to develop it through study and practice, but whether acquired or natural, the structural draftsman must somehow achieve an easy and comfortable use of this faculty.

The more advanced structural shop drawings are considered such because they incorporate some of the more intricate phases of descriptive geometry. Under this heading is included hip and valley work, bins and hoppers, various types of storage tanks and numerous other situations where steel members are framing at angles with each other and in several different planes. The usual procedure in training draftsmen is a block on top of block process beginning with the simple and elementary and progressing towards the intricate and complex. Some fabricators, however, who do a specialized line of work, are able to get out rather involved work utilizing draftsmen of limited overall experience by having experienced engineers to break the work down into component parts which are then detailed along formulated lines. Detailers thus trained are often of very little value except to those specific types of work.

The larger steel fabricators, especially those of national scope, have very definite standards which form and control the method of preparing shop details. These standards will vary from one company to another, and although none of the basic principles of engineering drawing will be violated, certain conventional methods will be set down which cannot be found in any textbook. Smaller fabricators have generally taken one of three routes; followed the standards set out by one of the larger fabricators; developed at quite some expense a book of standards of their own; used a hodgepodge of methods with every newly employed

draftsman who has experience elsewhere bringing ideas of his own. Smaller fabricators in the last category are quite numerous and the hardships worked on their shops by not having definite standards is considerable.

The business of operating independent detailing offices for the purpose of preparing shop drawings for a number of different fabricators is on the increase. Fabricators who use these services generally maintain a basic drafting department, and then "farm out" to these independent agencies such shop drawings which are above the capacity of their basic drafting unit. Such services are a convenience to the fabricator as it keeps him from having to expand and contract his drafting department according to the volume of business he is able to secure. Such "farming out," however, brings up the problem of standards and method of detailing. The independent detailer may be working for a dozen different fabricators and he is faced with the dilemma of using his own standards or conforming to a particular fabricator's standards either through study or conference.

All of this brings me to the point of making the statement that the time is full ripe for the establishment on a national scale of a standard practice of detailing structural steel and the conventions pertaining thereto. The American Institute of Steel Construction has recently published a book entitled "Structural Shop Drafting, Volume I" which is a step towards standardization on a national scale. This book is called a "textbook" and it is intended to assist in training men in the field of structural drafting, but it does not set down detailing practices except in a general way. It is my understanding that a Volume II is to be published later which will establish standards and procedures. The success of such a move will depend largely upon the degree of acceptance by the industry, and especially by those who have for years followed well established standards of their own. Volume I is authoritatively written and contains enough material on structural design to warrant it being used as a supplementary textbook in senior structural design courses.

In conclusion it can be said that the steel fabricating business occupies one of the pivotal points about which the construction industry revolves and it is good that the fabricators have organizations directed largely by Registered Professional Engineers who are capable of taking fine engineering designs prepared by Consulting Engineers and converting them faithfully into steel structures. Such work is very satisfying and challenges the best engineering talents. The steel fabricating business offers the young graduate an authoritative continuation of his engineering education, and though it does not promise him a disproportionate compensation, it does hold for those with ability and a desire to work many oportunities for advancement into the executive field. The steel business needs and deserves the sharpest men the engineering schools can produce and although the industry can compete for these men on an equal basis with other fields, students have too often been advised that other divisions of engineering were more lucrative. It is hoped that through the medium of such groups as this one, that authoritative information concerning various branches of industry can be disseminated to the students so that they might make their decisions without prejudice or false impressions.

A Simple Electronic Differential Analyzer as a Demonstration and Laboratory Aid to Instruction in Engineering

BY M. H. NICHOLS[1] AND D. W. HAGELBARGER[2]

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Introduction

The demonstration of such things as dynamics of mechanical systems, statics and dynamics of beams, etc., by mechanical means is often expensive and inconvenient. The demonstration of such idealizations as purely dry or purely viscous friction is difficult, if at all possible, by mechanical apparatus. Many of these demonstrations are more conveniently handled by use of an electronic differential analyzer and, in general, do not lose their instructional value. Over the past several years, the authors have used the electronic differential analyzer for laboratory instruction in an undergraduate instruments course and in a servomechanism course and have received enthusiastic response from the students. In addition to providing an insight into the behavior of the systems studied, setting up the differential analyzer, arranging the initial conditions, etc., help the students get a "feel" for differential equations as expressions of the behavior of physical systems.

The purpose of this paper is to describe the use of a simple electronic differential analyzer[3] for laboratory instruction and lecture demonstration. Several examples will be worked through completely and additional possibilities will be suggested. Upon sufficient experience, the extension of the computer to the demonstration of many other engineering problems becomes apparent. Although the apparatus, with the possible exception of the recording instrument, can be duplicated in most college shops, space does not permit a complete description of each component and a detailed description of the use of the analyzer. However, such information may be obtained in detail by writing to the first author and to emphasize this, a double asterisk (**) will in the following denote some of the topics on which detailed information is available. Since the fundamental theory of this type of computer is well discussed by Ragazzini, Randall, and Russell[1] and by Frost,[2] it will not be repeated in this paper.[4] The basic component of the analyzer is a high gain d.c. amplifier. The amplifiers used for the results presented in this

[1] Now at California Institute of Technology, Pasadena, California.

[2] Now at Bell Telephone Laboratories, Murray Hill, New Jersey.

[3] Another type of electronic computer, usually called an analogue computer, makes use of inductances, capacitances, and resistances, connected circuitwise to simulate the system under study. See, for example, McCann, Wilts, and Locanthi, IRE, *37*, 954 (1949); McCann and MacNeal, ASME Jour. Appl. Mech., *17*, 13 (1950) and references thereto. In the case of continuous media, the method of difference equations is used.

[4] It should be mentioned that Ragazzini et al.[1] use only the differentiator type of amplifier connection, whereas it was later found that the integrator type of connection is more practical and can be used to accomplish the same results. Frost[2] discusses the connections for integration.

paper are described by Ragazzini et al.[1] More recently Frost[2] has described a similar amplifier which may be more advantageous for demonstration purposes because it provides a higher current output which permits the use of a wider variety of recording and observing instruments. The recordings presented in this paper were made by a Bruch Development Company type *BL202* magnetic pen recorder but a wide variety of recording and observing instruments, including cathode ray oscilloscopes can be used. A complete description of the auxiliary power supplies, etc., may be obtained.**

Type of Systems Which Can Be Handled by a Simple Electronic Differential Analyzer

A differential analyzer can be arranged to obey the differential equations which describe the system to be investigated.[1, 2] With only the basic d.c. amplifier and simple condensers and resistors it is easy to handle ordinary linear differential equations of the type

$$(Ap^{m-n} + Bp^{m-n-1} + Cp^{m-n-2} + \cdots)y = (\alpha + \beta p^{-1} + \gamma p^{-2} + \cdots \eta p^{-n})x, \quad (1)$$

where p denotes differentiation by the independent variable (p^{-1} denotes integration), the coefficients A, B, C,$\cdots$, α, β, γ,$\cdots$, etc. are constants, y is the dependent variable and x is an arbitrary function of the independent variable. In many cases, x may be considered as a forcing function. It is also easy to handle systems of equations of the type (1)—i.e., coupled systems with only one independent variable but with several dependent variables. In the case of the differential analyzer described here, the independent variable becomes time and the variables x and y are voltages. Examples of systems which are described by equation (1) are simple one dimensional linear vibration,[4] seismic instruments,[4] linear servo systems,[5] uniform thin beams,[4, 6] etc. By using the d.c. amplifier in its non-linear range, it is possible to handle such things as dry friction,[4] bang-bang controlled servos, etc. By means of more complicated devices such as synchronously driven switches or potentiometers, servo multipliers, etc., more complicated differential equations can be handled[1, 2, 3] but these will not be discussed in this paper.

Use of the High Gain D.C. Amplifier to Perform Elementary Operations

Figures 1A and 1B on page 118 of Frost's paper[2] show how the d.c. amplifier can be used to sum and to integrate to a high degree of accuracy if the gain of the amplifier is sufficiently high. The relations given in connection with this figure can be easily proved by applying Kirchhoff's laws to the input terminal of the amplifier under the assumption that the gain of the amplifier and input resistance to the amplifier are both very large.[1, 2] In order to use the amplifiers as they are connected in Fig. 1 of Frost's paper, it is necessary that the output voltage be opposite in polarity from the input, otherwise the feed back connection would represent an unstable system. It is also possible to differentiate[1] but this is generally not practical because of the resultant amplification of stray 60-cycle pick up and the instability resulting from phase-shift characteristics of the amplifiers at high frequencies.

A general arrangement of amplifiers which obeys equation (1) with positive coefficients is shown in Fig. 1, in which the condensers are all taken as one microfarad for convenience, and all resistors as are in units of megohms.[5] In particular cases, there are alternative connections which sometimes make possible the elimination of one or more amplifiers, but Fig. 1 can be used as a guide for setting up the problem. The following

[5] In the case of negative coefficients, the appropriate connections should be changed from bus (1) to bus (2) or vice versa. That the arrangement of amplifiers in Fig. 1 satisfies equation (1) can be shown by applying Kirchhoff's current law to the junction "J."

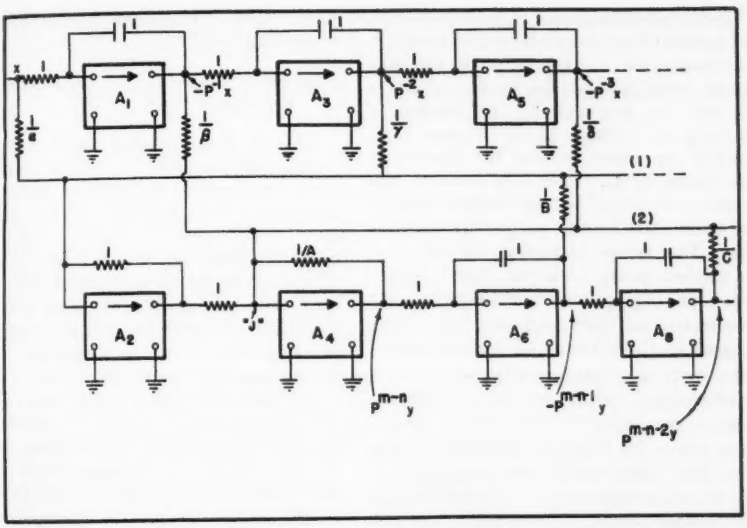

FIG. 1. General arrangement of amplifiers which obeys equation (1) with positive coefficients. All capacitors and resistors are in units of microfarads and megohms, respectively.

examples will illustrate the arrangement for some common engineering problems and will show how initial conditions are handled.

Examples

Example 1. One Degree of Freedom Vibration.

Consider the spring, mass, and viscous damper system represented by Fig. 23 on page 34 of reference (4). Let a force $x(t)$ act on the mass. Then equation (1) for this case becomes

$$(Ap^2 + Bp + C)y = x(t), \qquad (2)$$

where A represents the mass, B the viscous damping coefficient and C the spring constant, $\alpha = 1$, $\beta = \gamma = \delta = 0$. Referring to Fig. 1, it is seen that in this case amplifiers A_1, A_3, A_5, etc. are not used—i.e., only amplifiers A_2, A_4, A_6, and A_8 are used. It is also possible, and sometimes convenient for varying the parameters—i.e., mass, damping, and spring constant—to make the resistors $1/A$, $1/B$, etc. some nominal value, say one megohm, and to put a voltage divider of around 50,000 ohms total resistance across the outputs of amplifiers A_4, A_6, and A_8 so that the proper fraction of the output of these amplifiers can be fed back to the junction J.** The forcing function $x(t)$ may take the form of a step function voltage or a sinusoidal voltage both of which can be easily produced, the first by a battery and a switch and the second by simple electromechanical or electrical means.** Various sinusoidal frequencies can be combined for a Fourier series synthesis of $x(t)$ etc.[6]

[6] It should be mentioned that by using the proper feedback connection it is possible to handle equation (2) with only three amplifiers instead of the four indicated by Fig. 1.** Also, if $B > 0$ then it is possible to handle equation (2) with only one amplifier by means of added associated resistors and condensers (2).** This latter is essentially a combination of differential analyzer and analogue computer.

Initial conditions can be easily inserted by means of batteries and switches which are opened at time $t = t_0$.** In the case under consideration the initial condition y_0 can be inserted by connecting a battery of voltage y_0, by means of a switch (or relay), across the feed back condenser of A_3.** If y_0 is positive, the positive terminal of the battery should be connected to the output terminal of A_3. The initial condition on $(dy/dt)_{t_0}$ is applied in the same manner. Figure 2 is a photograph of a four amplifier unit connected to obey equation (2). The chassis on the left is an electromechanical sine wave generator constructed from a synchronous motor and a war surplus selsyn generator.** The initial condition relays are fastened to the top of the two feed back condensers which appear on the lower right side of the photograph. By proper adjustment of the input and feedback elements it is possible to change the time scale for more convenient observation of the output and to change the voltage level in the amplifiers for operation in the optimum voltage range.**

By using the computer connection from Fig. 1 it is easy to run off the steady state response for various values of the damping ratio[4] as a function of various sinusoidal forcing frequencies giving both amplitude and phase response.** Also various transient effects can be easily handled.**

Example 2. Spring and Mass with Dry Friction.

This is a non-linear problem[4] and cannot be handled by Fig. 1 but can easily be handled by making use of the saturation characteristic of the amplifier.** This can be done by using the same amplifier connection as for equation (2) except that the feed back resistor $1/B$ should be about 50,000 ohms and the feed back resistor from output to input of A_2 should be about 30 megohms. This causes amplifier A_2 to saturate and thus to put out a square voltage wave which changes sign each time the velocity, y, changes sign thereby representing a dry friction force. A voltage divider (of about 50,000 ohms total resistance) can be put across the output of amplifier A_2 in order that the desired amount of dry friction force can be fed into A_4. If a forcing function is desired, minus $z(t)$ can be fed through the resistance $1/a$ into A_4. Actually this connection of amplifier A_2 results in a square wave which is not symmetric about the zero voltage level. This defect can be rectified by the proper connection of an additional amplifier.** In most cases this asymmetry causes no trouble because its effect may be considered as a constant displacement of the system.

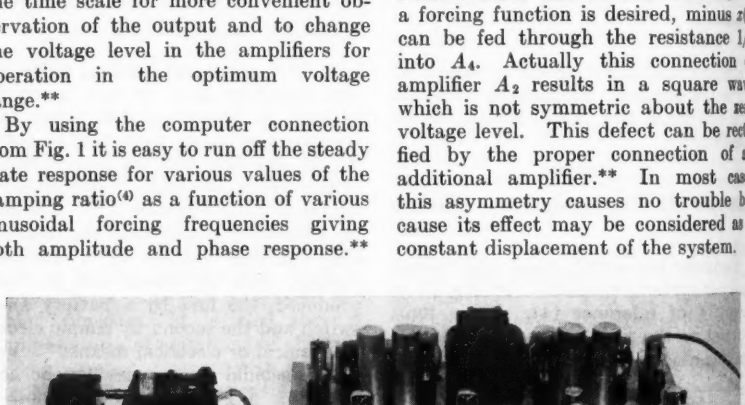

FIG. 2. Photograph of a four amplifier unit set up to obey equation (2) with an electromechanically generated sinusoidal forcing function.

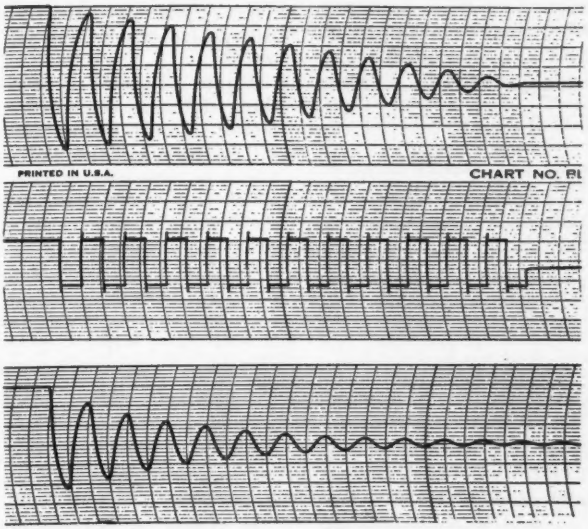

FIG. 3. Step function response of a mass and spring system with dry friction, top, as compared to the same system with viscous friction, bottom. The middle record is the dry friction force applied through the saturable amplifier; the overshoot is due to the recorder characteristic.

Figure 3 is a reproduction of a recording of a step function response of a spring and mass system with dry friction as compared to the same system with viscous friction. Combinations of dry and viscous friction in both transient and steady state can be handled by combining the methods of example 1 and example 2.

Example 3. Servomechanism.

From reference (5) page 177, the fundamental differential equation for a linear servomechanism with viscous output damping, error rate damping, and integral control may be written:

$$(Ap + B + Cp^{-1} + Dp^{-2})y = (\alpha + \beta p^{-1} + \gamma p^{-2})x, \quad (3)$$

where y is the output angle, x the input angle, A the output moment of inertia, $B = L + F$ (where L is the torque per unit error rate and F is the friction torque per unit output rate), C the torque per unit error angle, D the torque per unit time integral of error, $\alpha = L$, $\beta = C$, $\gamma = D$. This is directly handled by Fig. 1.

As an example, the response of a servomechanism to a ramp input function —i.e., the input function, $x(t)$, is a linear function of time starting at zero at time zero—will be investigated. Many ways of generating such a ramp function will be obvious, but a convenient one consisting of a single amplifier connected to integrate a constant voltage—i.e., to integrate a velocity step function—was used for this example.** The ramp function output was connected into the circuit derived from Fig. 1, which obeys equation (3), at the $x(t)$ terminals. The quantity $-y$ is taken off the output of A_6 and x is taken from the $x(t)$ terminal. If it is desired to obtain the output error $y - x$, the output of A_6 is added by a summing amplifier[2] to the ramp function voltage at $x(t)$.** The output of the summing amplifier is $y - x$.

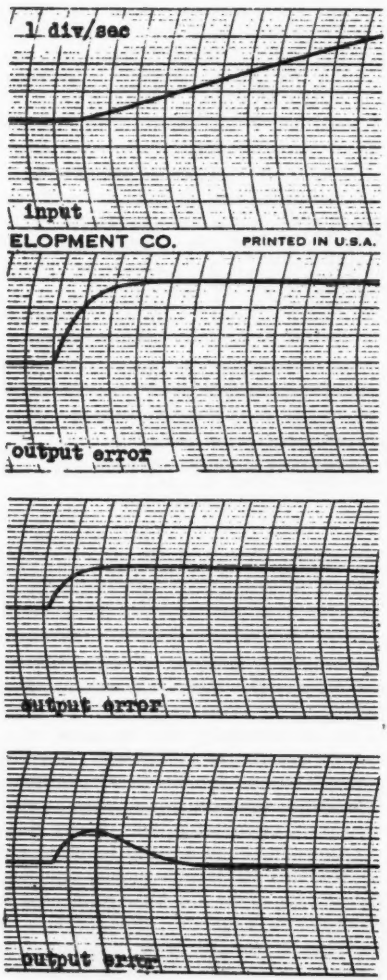

FIG. 4. Error between the output and the input of a servomechanism for a ramp function input. The top trace is the ramp function input; the next to top is the output error with viscous output damping; the next to bottom is output error with viscous output damping and error rate feed back; and the bottom is output error with viscous output damping, error rate feed back, and error integral feed back. All cases are critically damped.

Thus eight amplifiers are required. Alternative connections can be worked out.**

Figure 4 is made up of recordings for three different combinations of parameters. In this figure the ramp function $x(t)$ is recorded and the output error $y - x$ is recorded for each case. The latter is recorded with ten times the sensitivity of the former. The three cases are: Case I, $A = \frac{1}{4}$, $C = 1$, $\dot{x} = 0.1$, $F = 1$, $L = 0$, $D = 0$; Case II, $A = \frac{1}{4}$, $C = 1$, $\dot{x} = 0.1$, $F = \frac{1}{2}$, $L = \frac{1}{2}$, $D = 0$; Case III, $A = \frac{1}{4}$, $C = 1$, $\dot{x} = 0.1$, $F = \frac{1}{2}$, $L = \frac{1}{2}$, $D = \frac{1}{2}$. Since in each case $F + L = 1$ and $AC = \frac{1}{4}$, the damping is always critical. It is interesting to note that the addition of rate feed back halves the steady state error and that the further addition of integral control reduces the steady state error to zero.

It should be pointed out that the differential equation for a seismic instrument[4] can be written in a form identical to equation (3) in which only error and rate control are applied—i.e., $D = \gamma = 0$. In this case $y(t)$ is the coordinate of the seismically supported mass and $x(t)$ is the coordinate of the support of the seismic instrument. The reading of the instrument is $y - x$. One dimensional vibration isolation problems (see reference (4) page 85) can be handled in a similar way. Such things as dry friction and bang-bang control in servomechanisms can be handled by the saturation of the amplifiers as discussed in example 2.

Example 4. Coupled Systems—The Dynamic Vibration Absorber.

In order to handle linear coupled systems with one independent variable, the computer may be set up for each dependent variable in accordance with Fig. 1. Then the necessary cross connections are made. As an example of coupled systems, the problem of the damped vibration absorber will be treated. From reference (4) page 115 the differential equations of the system

with a sinusoidal forcing function can be written:

$$(A_1p^2 + B_{12}p + C_1 + C_{12})y_1 - (B_{12}p + C_{12})y_2 = P_0 \sin\omega t, \quad (4)$$

$$-(B_{12}p + C_{12})y_1 + (A_2p^2 + B_{12}p + C_{12})y_2 = 0, \quad (5)$$

where subscript 1 refers to the main mass, subscript 2 to the small mass, and B_{12} and C_{12} represent coupling terms. From Fig. 1 a computer set up is made for y_1 (without the coupling terms) consisting of amplifiers A_2,[1] A_4,[1] A_6,[1] and A_3.[1] A similar set up consisting of A_2,[2] A_4,[2] A_6,[2] and A_3[2] is made for y_2. A forcing function $P_0 \sin\omega t$ is inserted at the x_1 terminals. A resistance of value $1/C_{12}$ is connected between the output of A_3[1] and input of A_2[2] and another resistance $1/C_{12}$ between the output of A_3[2] and the input of A_2.[1] A resistance of value $1/B_{12}$ is connected between the output of A_3[1] and the input of A_4[2] and another resistance $1/B_{12}$ between the output of A_6[2] and the input of A_4.[1] This completes the set up.

By way of illustration, the damped dynamic vibration absorber discussed in the example in reference (4) page 128, will be simulated with $C_{12} = 8.4$ lb./in. and $B_{12} = 0.054$ lb. sec./in. It turns out that with these values it is desirable to change the independent variable to a new time scale τ such that $\tau = 25t$ and to divide the equation through by 100.** This gives in terms of megohms using slugs, feet, and seconds: $1/A_1 = 0.515$, $1/(C_1 + C_{12}) = 0.0757$, $1/A_2 = 5.15$, $1/B_{12} = 6.17$, $1/C_{12} = 0.992$. Figure 5 shows the steady state response of this system to a forcing function of 53 radians per second with equal sensitivity in each

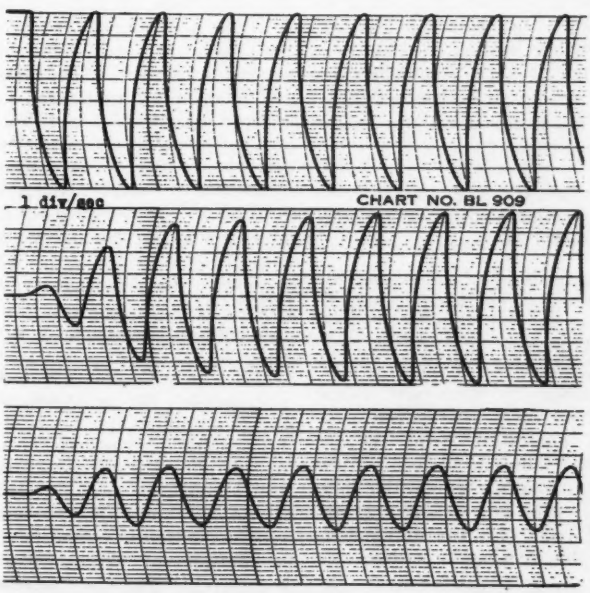

FIG. 5. Response of the damped vibration absorber to a sinusoidal forcing function. The top record is the forcing function, the center record is the deflection of the small mass and the bottom record is the deflection of the large mass. All the records were taken with the same sensitivity.

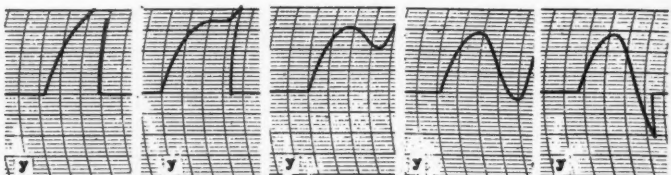

FIG. 6. Five trial solutions for the deflection of a uniform beam with uniform load hinged at the ends obtained by successive increases in V_a. The upper records are of y and the lower ones of y''. The fifth trial gives the proper solution because the y'' and y are zero simultaneously.

channel of the recorder. The ratio of the amplitude of y_1 to P_0 from Fig. 5 is $2.9/8.0 = 0.36$. Since this response was obtained with one unit of $P_0/100$—i.e., with 100 units of P_0—the true deflection of the main mass is $0.36/100 = 0.0036$ feet which is in agreement with the result of reference (4) page 128.

Example 5. Boundary Value Problems—The Thin Uniform Beam with Static Uniform Load

One of the fields in which the differential analyzer is of particular practical use is the solution of boundary value problems. Also the method used is illustrative of numerical methods of obtaining solutions to boundary value problems which can not be solved conveniently in analytical form. As an illustration, the thin uniform beam with static uniform loading and with both ends hinged will be treated. From reference (4) page 179, the differential equation for this case can be written

$$Ap^4y \doteq W, \qquad (6)$$

where $A = EI$, y is the deflection of the beam, p denotes differentiation with respect to the distance x along the beam, and W is the load per unit length. The end conditions are $y(0) = y(L) = y''(0) = y''(L) = 0$, where L is the length of the beam. A convenient method of getting a solution which satisfies these end conditions is to arrange a computer to obey equation (6) in which the independent variable becomes time t. The conditions $y(0) = y''(0) = 0$ are imposed by means of switches and the ratio of $y'(0)$ to $y'''(0)$ is varied until at some later time T, the conditions $y(T) = y''(T) = 0$ are satisfied. This then is a solution for the case of both ends hinged.

A computer arrangement which obeys equation (6) follows directly from Fig. 1 in which $B = C = D = E = \beta = \gamma = \delta = 0$ so that the arrangement consists only of amplifiers A_2, A_4, A_6, A_8, A_{10} and A_{12}. Actually, it is possible to use only four amplifiers if properly connected.** Initial conditions are imposed by means of switches which short circuit the feed back condenser of amplifiers A_8 and A_{12} the outputs of which are y'' and y, respectively, and by switches which connect a battery of voltage V_a across the feed back condenser of A_6 and a voltage of value V_b across the condenser of A_{10} the outputs of which are $-y'''$

and $-y'$, respectively. All four switches are opened simultaneously at time $t = 0$. The input at the $x(t)$ terminals of Fig. 1 is a voltage of some convenient value V. The voltage V_a is then varied and solutions tried until a solution which satisfies the end conditions at some later time T is obtained. Figure 6 is a recording of y and y'' for five trial solutions obtained by successive settings of V_a. The fifth trial satisfies the end conditions. Fig. 7 is a recording of y, y', y'' and y''' for the correct solution.

In order to obtain numerical results for a particular problem it is necessary to obtain a relation between the computer length T and the actual length L by making the substitution $t = Tx/L$. The relation is **: $W/EI = (T^4/L^4)V$, where V = the input voltage to the computer and with $1/\alpha = 1$ megohm. Corresponding to any point t in the computer solution the bending moment is given by $EI(T^2/L^2)y''$ and the shear force by $EI(T^3/L^3)y'''$. Since the problem is linear, the displacement, bending moment, etc., can be determined from any loading by simply multiplying the corresponding quantities from the computer solution by the ratio of the desired loading to the computer solution loading calculated from the above relation between W and V. A convenient way to

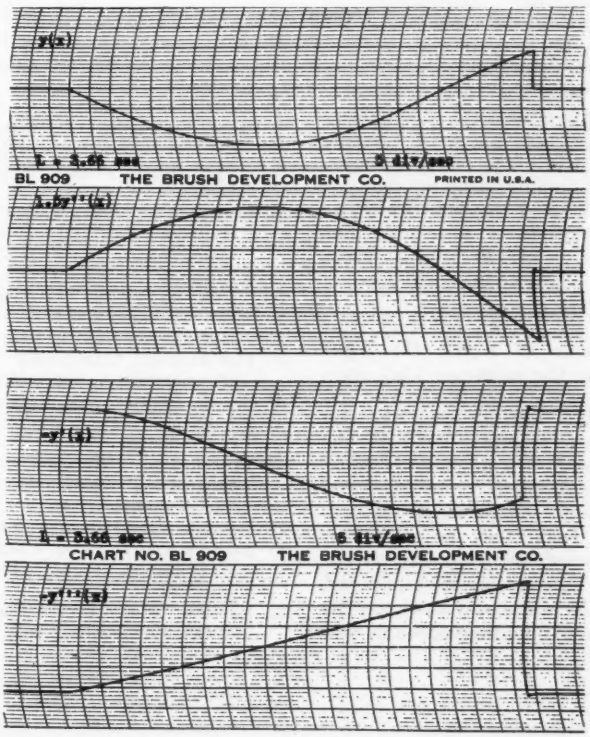

FIG. 7. Recording of y, y', y'', and y''' for a uniform beam with uniform load hinged at the ends.

determine the values of y, y', y'' and y''' from the computer solution is to apply the voltage V directly to each channel of the recorder and thus determine the deflection, R_v, in each channel produced by the voltage V. Then the values of y, y', y'', and y''' are the corresponding deflections divided by the R_v for the respective channel. As an example, consider the recordings of Fig. 7. For the y channel $R_v = 6.0$. From Fig. 7 the maximum deflection of y is about fourteen units. Thus $y_{max} = 14/6.0 = 2.3$ units. Also from the figure, $T = 3.66$ seconds. Hence, from above $W = 180\ EI/L^4$. Suppose that the problem to be solved is for a beam with $L = 1$, $EI = 1$ and $W = 1$. Thus the computer solution corresponds to $W = 180$. Hence, the value of y_{max} for $W = 1$ is $2.3/180 = 0.013$ units. From reference (7), page 121, the corresponding calculated value is $5/38.4 = 0.013$. Similarly for the y'' channel, $R_v = 5.6$ and from the record $1.5\ y''_{max} = 15$. Hence, $y''_{max} = 15/(1.5 \times 5.6) = 1.8$ units. Thus the maximum bending moment $M_{max} = EI(T^2/L^2)y''_{max} = 24$ which, as before, corresponds to $W = 180$. For $W = 1$, $M_{max} = 24/180 = 0.13$. From reference (7) page 121 the corresponding value is 1/8.

It should be pointed out that it is always possible to adjust the input voltage V (or the resistance $1/\alpha$), each time adjusting the ratio of the two unspecified initial voltages until the end conditions are satisfied, so that the computer length T is numerically equal to the actual length L (or to any other specified value). Other means of supporting the beam such as cantilever, clamped-clamped, etc., can be investigated simply by imposing the proper end conditions. It is also easy to obtain the normal modes of vibrations of beams.[6] **

Conclusion

Many examples of engineering problems such as consecutive reactions,[8] radioactive decay,[9] etc., can be easily demonstrated.** There are also a few simple precautions which must be observed in order to obtain accurate and reliable results.**

The authors are indebted to Professor C. E. Howe of Oberlin College, who, while at the University of Michigan, worked out many computer connections and ran many records some of which are included in this paper. The authors are also indebted to Professor L. L. Rauch of the University of Michigan, for criticism of the manuscript and for assistance in the preparation of the manuscript.

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TIMELY TIPS

Wave Velocities Above the Velocity of Sound

By R. C. BINDER

Professor of Mechanical Engineering, Purdue University

In various courses involving the flow of a compressible fluid there may arise a pedagogical problem concerning the velocity of a pressure wave. For example, students may ask if a pressure wave can move faster than the velocity of sound. An instructor, particularly in an undergraduate course, may like to have available a relatively simple and short quantitative analysis to answer questions of this sort. The following discussion outlines a quantitative study which does not involve differential equations. This study may be of help to instructors confronted with this pedagogical problem.

Imagine a cylindrical tube with rigid walls filled with a gas initially at rest, as illustrated in Fig. 1a. It will be assumed that the motion is one-dimensional, with no heat transfer, and no friction. Picture the pressure wave caused by the motion of the piston to the right in the tube. The piston moves with the velocity V_2; just ahead of the piston the gas static pressure is p_2. Some distance ahead of the piston the gas is at rest, the velocity V_1 is zero, and the static pressure is p_1.

There is a pressure wave travelling to the right with the velocity a because of the motion of the piston. Across this compression wave there is a sudden change in static pressure from p_2 to p_1.

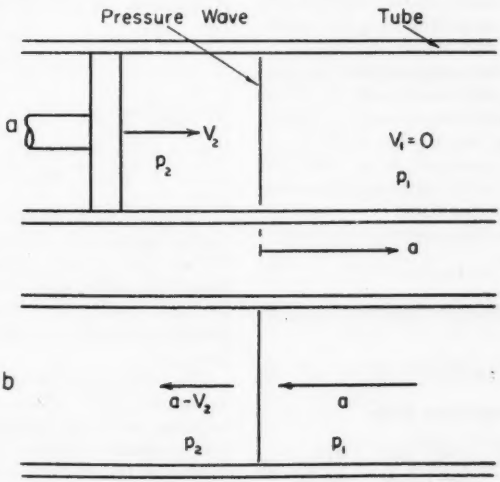

FIG. 1. Notation for pressure wave study.

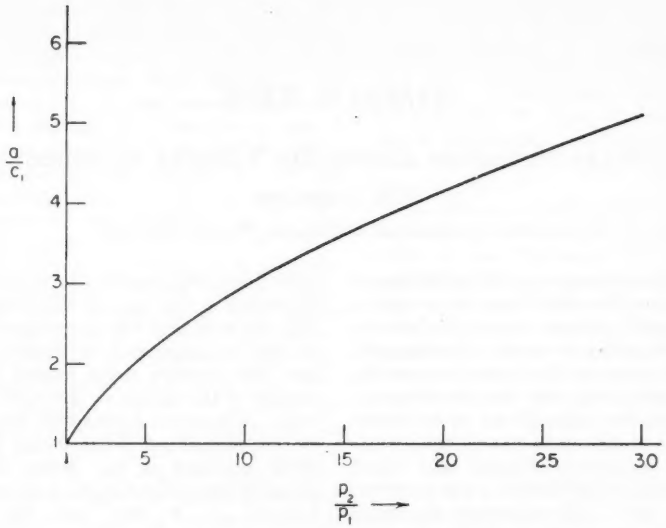

FIG. 2. Wave velocity ratio versus pressure ratio, for $k = 1.4$.

Figure 1a illustrates the pressure wave at a certain instant at a certain position in the tube. Picture an observer moving along with the wave, as illustrated in Fig. 1b. The same relative motion can be obtained by superimposing the velocity $-a$ on the flow shown in Fig. 1a.

In Fig. 1b the gas approaches the compression wave with a velocity a to the left, a static pressure p_1, and a density ρ_1. After the wave the velocity is $(a - V_2)$, the pressure is p_2, and the density is ρ_2. Let A represent the cross-sectional area of the tube.

The equation of continuity becomes

$$A a \rho_1 = A \rho_2 (a - V_2). \qquad (1)$$

The momentum or dynamic equation gives

$$(p_1 - p_2)A = A \rho_1 a[(a - V_2) - a]. \qquad (2)$$

The energy equation gives

$$\frac{(a - V_2)^2 - a^2}{2} = \frac{k}{k-1}\left(\frac{p_1}{\rho_1} - \frac{p_2}{\rho_2}\right), \qquad (3)$$

where k is the ratio of specific heats.

Equation (1) can be employed to give an expression for ρ_2 that can be substituted in Equation (3). Equation (2) can be used to give an expression for V_2 which can be substituted in Equation (3). Let

$$c_1 = \sqrt{\frac{kp_1}{\rho_1}}.$$

The final result of eliminating ρ_2 and V_2 is

$$\frac{a}{c_1} = \left(\frac{k-1}{2k} + \left(\frac{p_2}{p_1}\right)\left(\frac{k+1}{2k}\right)\right)^{\frac{1}{2}}. \qquad (4)$$

Consider first the special case in which p_2/p_1 equals 1. Then Equation (4) shows that $a = c_1$. The velocity c_1 is variously called the "acoustic" velocity or the velocity of "sound" for the gas having a density ρ_1 and a static pressure p_1.

We could say that the pressure change is infinitesimal across a pressure wave moving with the acoustic velocity. If the pressure change $p_2 - p_1$ is finite, however, the velocity of the compression wave is *higher* than the acoustic velocity. This fact is demonstrated by the plot in

Fig. 2 showing the velocity ratio a/c_1 as a function of p_2/p_1. At the higher pressure ratios the velocity a is considerably higher than the acoustic velocity c_1. In other words, we could say that the acoustic velocity is the *lowest* velocity of a compression wave.

A qualitative illustration can be provided by studying a blunt nose projectile moving through air at a supersonic speed. Ahead of the nose of the projectile is a normal compression shock (part of the bow wave) which is moving with the speed of the projectile. This compression wave moves at a speed higher than the velocity of sound. Across the compression wave there is a finite change in pressure.

Formulas for the Center of Hydrostatic Pressure

By GEORGE P. LOWEKE

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The determination of the vertical location of the center of pressure on plane surfaces is usually the only formula derived in textbooks on hydraulics and fluid mechanics. Little attention is given to the determination of the lateral location. This can be determined from a median line, if one exists, or from the symmetry of the figures which are ordinarily encountered in engineering. No formula is therefore offered for locating the center of pressure laterally as is done in the vertical determination of this point. In cases where the fiugres are not symmetircal, however, the engineer usually has only one recourse, that is to proceed from the beginning of the problem by determining a pressure moment by integration. It is interesting to note that the horizontal and vertical location of the center of pressure can be found from formulas that are essentially the same, and could always be treated together when teaching the subject rather than to consider the lateral location as a separate problem.

The formula for the vertical location of the center of pressure, as derived in all texts treating the subject, is,

$$\epsilon_{\bar{y}} = \frac{I_{\bar{y}}}{\bar{y}A},$$

where $\epsilon_{\bar{y}}$ is the location of the center of pressure below the centroid of the area, $I_{\bar{y}}$ is the second moment of the area about an axis through the centroid parallel to the surface of the liquid, and $\bar{y}A$ is the first moment of the area about an axis in the plane of the area and lying in the surface of the liquid.

The location of the center of pressure laterally is defined by the equation

$$X_{c.p.} = \frac{M}{F},$$

where M is the pressure moment taken about any vertical axis and F is the hydrostatic force on the plane. For an inclined plane as shown in Fig. 1, integrating over the area, gives

$$M = \int\int wyx \sin\theta \, dy \, dx,$$

$$= w \sin\theta \, I_{xy},$$

where I_{xy} is the product of inertia of the area about the x and y axes. Also

$$F = w \sin\theta \int\int y \, dy \, dx,$$

$$= w \sin\theta \, \bar{y}A.$$

By definition

$$X_{c.p.} = \frac{w \sin\theta \, I_{xy}}{w \sin\theta \, \bar{y}A} = \frac{I_{xy}}{\bar{y}A}.$$

This form can be reduced by the paral-

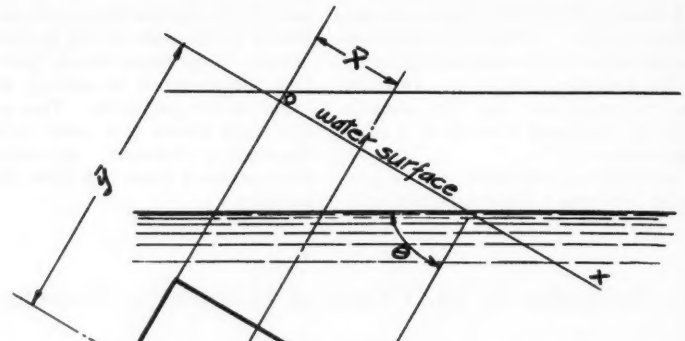

FIG. 1. Showing the vertical and horizontal location of the center of pressure on a submerged plane area by analogous formulas.

lel axis theorem, since

$$I_{xy} = I_{\bar{x}\bar{y}} + \bar{x}\bar{y}A,$$

where $I_{\bar{x}\bar{y}}$ is the product of inertia about parallel axes through the centroid of the immersed plate at distance $\bar{x}$, $\bar{y}$ from the original axes.
Then

$$X_{c.p.} = \frac{I_{\bar{x}\bar{y}} + \bar{x}\bar{y}A}{\bar{y}A} = \frac{I_{\bar{x}\bar{y}}}{\bar{y}A} + \bar{x}.$$

Putting $X_{c.p.} - \bar{x} = \epsilon_{\bar{x}}$ the lateral displacement of the center of pressure from the centroid is

$$\epsilon_{\bar{x}} = \frac{I_{\bar{x}\bar{y}}}{\bar{y}A}.$$

The similarity of the equations for $\epsilon_{\bar{x}}$ and $\epsilon_{\bar{y}}$ establishes uniformity in the computation of these quantities and makes it easier for the student to retain the whole concept. The quantity $I_{\bar{y}}$ is usually obtainable form handbooks. In cases where $I_{\bar{x}\bar{y}}$ cannot be readily obtained, this method permits the computation of the center of pressure entirely by the use of standard techniques easily obtainable in all standard works on elementary mechanics. When the submerged plane figure is symmetrical about a vertical axis, the product of inertia about axes through the centroid is zero, in which case $\epsilon_{\bar{x}}$ becomes zero.

Candid Comments

Dear Professor Bronwell:

I was interested to note under "Candid Comments" in the March issue of the JOURNAL an article by Professor Snader of Norwich University entitled "The First Engineering School."

We all realize that Americans have a remarkable propensity for claiming firsts, biggests, bests, etc., in practically all fields of man's endeavors. Therefore it was with a mixed feeling of amusement and injured pride that I read the claim that Norwich was the first educational institution in the country to teach civil engineering. It so happens, that this distinction—claimed by both Rensselaer and Norwich—actually goes back before either of these institutions were founded, to the United States Military Academy at West Point.

Founded in 1802 by an Act of Congress, West Point was initially a school for Engineers and Artillerists. However, without adequate support, it struggled along as best it could until the War of 1812 suddenly focussed the attention of the Congress on the Military Academy. An Act was passed in April of 1812 reorganizing the Academy and establishing among others, the Professorship of Engineering. It is interesting to note that Alden Partridge (who founded Norwich in 1820) graduated from West Point in 1806, was Professor of Engineering there from 1813–15, and then was Superintendent until 1817.

Joseph Gardner Swift, the first graduate of West Point (Class of 1802) resigned from the service in 1818 to become a distinguised civil engineer. Other early graduates who became civil engineers, included W. G. McNeill, Class of 1817; Andrew Talcott 1818, Jonathan Prescott, and Charles Dimmock of the Class of 1821, 5 graduates in 1822, 2 in 1823 and 4 in 1824. To bear out further the fact that even in those early days, West Point produced something besides soldiers (and engineers), consider the following: Horace Webster, of the Class of 1818 was President of College, City of New York from its founding in 1848 until 1869. Edward H. Courtenay, Class of 1821, was for eleven years, the Professor of Mathematics at the University of Virginia. Thomas R. Ingalls, Class of 1822, was President of Jefferson College, in Louisiana.

Yours sincerely,

ELVIN R. HEIBERG,
Colonel, USA,
Professor of Mechanics

1951 Oak Ridge Summer Symposium

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Section Meetings

Section	*Location of Meeting*	*Dates*	*Chairman of Section*
Allegheny	Carnegie Institute	April, 1951	D. F. Miner, Carnegie Institute
Illinois-Indiana	Northwestern University	May 12, 1951	W. C. Knopf, Northwestern University
Kansas-Nebraska	University of Nebraska	Nov. 16–17, 1951	Kenneth Rose, University of Kansas
Michigan	General Motors Institute, Flint, Michigan	May 5, 1951	H. M. Dent, General Motors Institute
Middle Atlantic	Rutgers University	May 12, 1951	S. J Tracy, Jr., City College of New York
Missouri	University of Missouri	April 7, 1951	R. J. W. Koopman, Washington University
National Capital Area	George Washington University	Feb. 6, 1951	R. B. Allen, University of Maryland
	U. S. Naval Post Graduate School	May 12, 1951	
New England	Rhode Island State College	Oct. 13, 1951	W. C. White, Northeastern University
* North Midwest	University of Minnesota		E. W. Johnson, University of Minnesota
Ohio	Ohio State University		W. F. Brown, University of Toledo
Pacific Northwest	University of Idaho	May 4–5, 1951	A. S. Janssen, University of Idaho
Pacific Southwest	University of Nevada	Dec. 27–28, 1951	S. F. Duncan, University of Southern California
Rocky Mountain	Utah State Agricultural College, Logan, Utah	April 13–14, 1951	J. E. Christiansen, Utah State Agricultural College
Southeastern	Buena Vista Hotel, Biloxi, Miss.	March 22, 23, 24, 1951	E. B. Norris, Virginia Polytechnic Institute
* Southwestern	Texas A. & M. College		R. L. Pourifoy, Texas A. & M. College
Upper New York	Clarkson College	Oct. 5–6, 1951	W. H. Allison, Clarkson College

Members of the Society are welcome at all Section Meetings

* No Date Set.

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AGGELER, CECIL J., Instructor in Engineering, City College of San Francisco, San Francisco, Calif. A. E. Edstrom, H. R. Edmison.

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524 new members this year

College Notes

The first of a series of special summer graduate programs in engineering will be offered by **North Carolina State College,** during the 12-week period June 11–August 31. The new programs are designed to make advanced courses available to anyone interested, and to enable graduate students to obtain a Master of Science degree with three summers' work. Conceived as a teacher-aid program, the session will be subsidized by the General Education Board, with the intention of providing an opportunity for young engineering teachers in the South to obtain advanced knowledge and broader concepts of their chosen field of scientific activity. Three Departments—Ceramic Engineering, Chemical Engineering, and Electrical Engineering—will each offer a full program of graduate courses, and advanced work in Mathematics and Physics will also be available. In a series of three such summer sessions, a complete and integrated program is achieved, fulfilling all requirements for an M.S. degree in these three fields. Credits may also be applied toward a Ph.D. degree, and are transferable.

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